Evaluation of landscape architecture 3D modeling tools and practices in Finland

Master’s thesis, Aalto University

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1. Abstract

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Abstract

In Finland clients are increasingly demanding 3D models that are to be used in "combination models" during construction of infrastructure projects, which has led to a need for landscape architecture offices to acquire 3D modeling software. Especially older landscape architects do not have personal experience in doing 3D modeling, which is why the 3D modeling process, including the benefits and limitations, is not fully understood.

Some research has already been done of the benefits and limitations of landscape architecture, but more research is needed on how these benefits and deficits apply to different 3D modeling software. This information can be useful for landscape architects and offices, who are beginning to include 3D modeling in their work process, and are wondering which software would best suit their needs.

The goal of this Master's thesis is to investigate how 3D modeling is done in Finland and how 3D modeling could better be used to benefit the needs of landscape architecture. In order to develop 3D modeling, the deficits of 3D modeling must first be found. After this it can be considered how to improve these deficits. The benefits of 3D modeling are also studied, because another way to develop 3D modeling is to increase the benefits.

In order to find the currently known benefits and deficits, a literature review is conducted. The literature review outlines the knowledge gap, which helps to narrow down the research questions. Answers to the research questions are researched with a survey conducted with Finnish landscape architects and comparing 5 commonly used 3D modeling software in Finland in practice.

In the conclusions the differences between these 5 software are outlined, and it is determined that the differences between 3D modeling software are largely explained by the target audience for those software. The development of 3D modeling requires software developers to acknowledge landscape architecture as one of the target audiences, for which plug-ins are one possible short-term solution. In the long term productivity would be increased by a BIM software developed for landscape architecture that could produce construction drawings and make better use of inital data.

As the only university to teach landscape architecture in Finland, Aalto University has a high influence on which software future landscape architects use, so the university should check periodically if 3D modeling software that are best suited for landscape architecture are installed and included in teaching. Newly graduated landscape architects take their skills with them to offices and can suggest new software and work methods.

Keywords **landscape architecture**, 3D modeling, software, tools, features, comparison, survey, literature review, development, plug-in

Tekijä Elina Haapaluoma
Työn nimi Arviointi maisema-arkkitehtuurin 3D-mallintamisen työkaluista ja käytännöistä Suomessa
Laitos Arkkitehtuurin laitos
Koulutusohjelma Maisema-arkkitehtuuri
Vuosi 2019 Sivumäärä 226 Kieli Englanti

Tiivistelmä

Suomessa asiakkaat haluavat enenevässä määrin maisema-arkkitehtitoimistoilta 3D-malleja infrastruktuurihankkeissa käytettäviä yhdistelmätietomalleja varten, mikä on johtanut siihen, että maisema-arkkitehtitoimistojen täytyy ottaa 3D-mallinnusohjelmistoja käyttöönsä. Varsinkaan vanhemmilla maisema-arkkitehdeillä ei ole henkilökohtaista kokemusta 3D-mallintamisesta, minkä vuoksi 3D-mallinnuksen prosessia, etuja ja haittoja ei täysin ymmärretä.

Joitain tutkimuksia on jo tehty maisema-arkkitehtuurin 3D-mallinnuksen eduista ja haitoista, mutta lisätutkimusta tarvitaan siitä, miten nämä todetut edut ja haitat pätevät eri 3D-mallinnusohjelmistoihin. Tämä tieto voi olla hyödyksi maisema-arkkitehdeille ja toimistoille, jotka alkavat sisällyttää 3D-mallintamista työprosessiinsa ja miettivät, mikä ohjelmisto sopisi tällä hetkellä parhaiten heidän tarpeisiinsa.

Tämän diplomityön tavoite on tutkia, miten 3D-mallinnusta käytetään Suomessa ja millä keinoilla 3D-mallien hyödyntämistä voisi parantaa maisema-arkkitehtuurin tarpeita ajatellen. 3D-mallinnuksen kehittämiseksi tulee ensin selvittää, mitä ongelmia 3D-mallinnuksessa on. Vasta sitten voi harkita, miten ongelmia voisi parantaa. Myös 3D-mallinnuksen tuomat edut ovat yhtenä tutkimuksen kohteena, sillä toinen tapa kehittää 3D-mallinnusta on lisätä sen tuomia etuja.

Nykyisin tiedossa olevien etujen ja haittojen selvittämiseksi suoritetaan kirjallisuustutkimus. Kirjallisuustutkimus auttaa artikuloimaan tutkimustiedosta puuttuvan aukon, minkä perusteella tutkimuskysymyksiä tarkennetaan. Näihin tutkimuskysymyksiin etsitään vastauksia suorittamalla tutkimuskysely suomalaisille maisema-arkkitehdeille ja tekemällä käytännön vertailu viidestä Suomessa yleisesti käytössä olevasta 3D-mallinnusohjelmasta.

Johtopäätöksissä esitellään vertailtujen mallinnusohjelmien erot, ja todetaan ohjelmien välisten erojen selittyvän pitkälti 3D-mallinnusohjelmien kohderyhmien perusteella. 3D-mallinnuksen kehitys vaatii, että ohjelmistokehittäjät huomioivat maisema-arkkitehtuurin kohderyhmänä, mihin nykyisiin ohjelmistoihin kehitetyt lisäosat ovat yksi lyhyen tähtäimen ratkaisu. Pitkällä tähtäimellä työskentelyä tehostaisi maisema-arkkitehtuurin tarpeisiin kehitetty BIM-ohjelmisto, joka pystyy tuottamaan rakennepiirroksia ja hyödyntämään lähtötietoja nykyistä tehokkaammin.

Ainoana maisema-arkkitehtuuria opettavana yliopistona Suomessa Aalto-yliopiston opetuksella on suuri vaikutus käytettäviin ohjelmiin, joten yliopiston tulisi tarkistaa säännöllisesti, onko maisema-arkkitehtuurin 3D-mallinnukseen parhaiten soveltuvia ohjelmistoja asennettuna ja sisällytettynä opetukseen. Vastavalmistuneet maisema-arkkitehdit vievät osaamisensa mukanaan toimistoihin ja voivat ehdottaa uusia ohjelmistoja ja työskentelymenetelmiä.

Avainsanat maisema-arkkitehtuuri, 3D-mallinnus, ohjelmisto, työkalut, ominaisuudet, vertailu, kysely, kirjallisuustutkimus. kehitys, plug-in

2. Introduction

2.1. Problem statement

In Finland, clients are increasingly demanding 3D models of landscape architecture projects[1]. These 3D models are used to visualize the project for a layman audience or to aid in the construction phase of the project. In infrastructure projects the YIV (Yleiset inframallivaatimukset = General Inframodel Requirements) guidelines are used to determine the level of 3D modeling required. These guidelines are provided by buildingSMART Finland, which is a “special main committee” in The Building Information Foundation RTS sr (Rakennustietosäätiön erityispäätoimikunta). The 3D models defined by buildingSMART for the different stages of the design process are the “initial data model” (lähtötietomalli), “design model”(suunnitelmamalli), “combination model” (yhdistelmämalli) and the “as-planned model” (toteutusmalli).

In “combination models” the 3D models from all professions involved in the project are combined as a whole. The combination model helps to see the internal inconsistencies in the project before construction is begun, saving time and money by avoiding construction errors. According to “Integrating BIM Technology into Landscape Architecture” (Sipes, 2014) ”Norway, Denmark, Sweden, and Finland were among the earliest countries to adopt model-based design and to push for interoperability and open standards”. The YIV guidelines were created due to the largest infrastructure clients in Finland aiming to adopt model-based design (Niskanen, 2015). The goal of model-based design is better communication between professions, increased quality and efficiency of construction and having better control over the project (Niskanen, 2015).

Landscape 3D models are required in “combination models” in order to understand how structures are constructed on the planned landforms. Because of the overall increase in model-based design in infrastructure, landscape architects are now also required to provide 3D models of their designs in many projects - not only for visualization purposes, but for construction purposes. This demand for landscape 3D models puts pressure on offices to adopt 3D modeling software and to acquire the skills needed to use the software. However, currently there is no specific software designed for 3D modeling landscape architecture. Instead, each office is coming up with their own solutions from a variety of software and workflows.

The increasing demand for landscape building information models has brought up the start of the “MaisemaBIM” project (LandscapeBIM) that sets out to define the required level of detail for landscape architecture BIM objects (Juurinen et al, 2019). The definitions of landscape architecture elements created in the MaisemaBIM project are intended to be imported into a BIM file format that is in use in Finland, called “Inframodel”, based on LandXML [2]. Currently most landscape models used in combination models are simply bare 3D models without any information attached, because the BIM file formats in use are not able to recognize landscape elements (Sipes, 2014) . The Finnish Landscape BIM project is trying to define which information should ideally be included in a landscape information model file format, and what information is sufficient at the moment, considering that most offices and most software are currently not capable of producing landscape information models at the ideal level. As software and methods improve, it is advised to try to reach the ideal level whenever possible - however, the focus of this thesis is on the currently achieved level of 3D modeling, which mainly consists of bare 3D models without information attached.

With demands for landscape information models from clients, offices are forced to come up with solutions not only for BIM, but for basic landscape architecture 3D modeling as well. Many landscape architects from the older generation have never done 3D modeling[3], and have to rely on suggestions from experts - often not even in the field of landscape architecture - to decide on which software to use, and hire people from the younger generation to do the 3D modeling. When the people doing the main design work are not acquainted with 3D modeling, the 3D modeling is often left as an additional step at the end of the design, perhaps viewed as a burden caused by demands from the client. This leads to offices not having a full understanding of the benefits of 3D modeling, and how to integrate it as part of the workflow.

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1 This is alluded to in the survey completed with Finnish landscape architects in this study. In the question “How important have these reasons been for you in deciding to use a 3D model for your project?” with 49 respondents, 5 respondents added “client demands” as an additional reason.

2 LandXML is explained in the software comparison in the file formats section.

3 According to the survey, 36% of those in a leading position had done 3D modeling at work compared to 63% of employees, and 28% had done 3D modeling during studies compared to 57% of employees and 83% of students.

To get the full benefits of 3D modeling in landscape architecture, 3D models should be utilised as part of the design process. During their studies, younger generation landscape architects are already doing this, but not without problems. The abundance of different 3D modeling software that could be used for landscape architecture causes confusion for beginning 3D modelers: “Which software should I learn? Which software do offices use? Which software benefits my design best? Which software fits my workflow?” This, combined with the fact that no software is currently perfect for landscape architecture, can lead to an endless chase for the best software and the best workflow - and adds additional burden to the already arduous process of learning a new software.

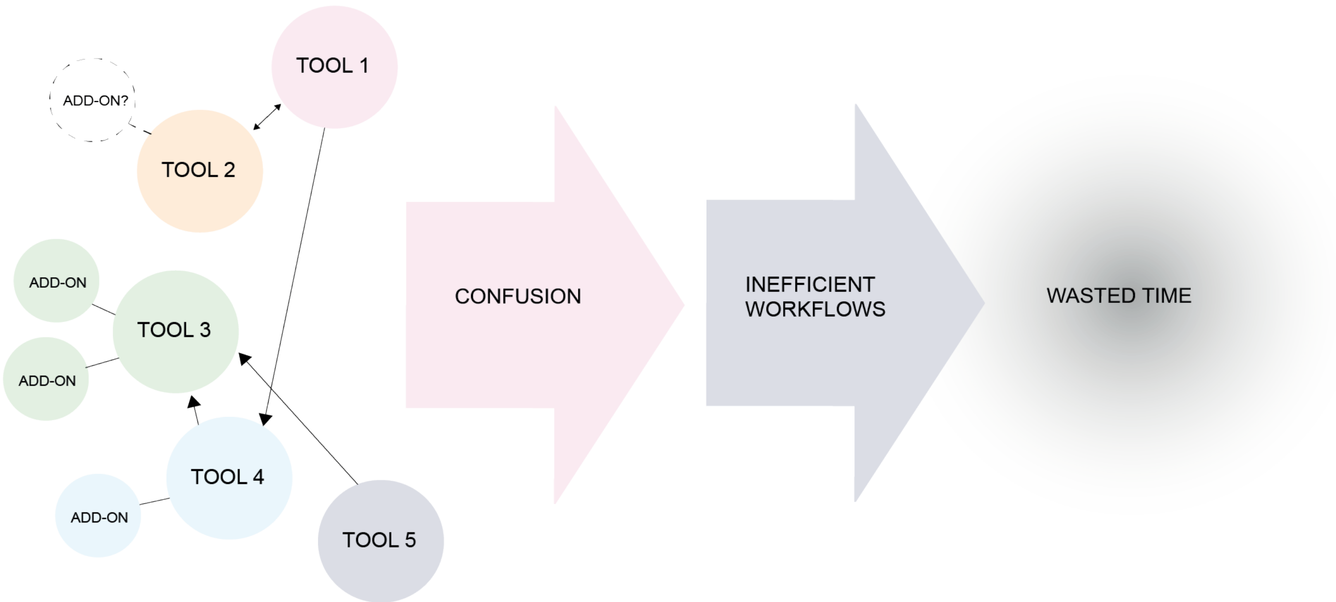

Figure 1. Depiction of how difficulties with software selection affect outcomes.

At Aalto University Department of Architecture athe following 3D modeling software are currently installed:

- Google Sketchup
- Rhinoceros 3D
- Blender
- Revit
- ArchiCAD
- 3DS Max
- Autodesk Maya
- Cinema 4D

At least Google Sketchup, Rhinoceros 3D and Microstation have been taught to landscape architects for 3D modeling. However, some offices use ArchiCAD and Revit, some even 3DS Max and Blender. Offices also use some software programs that are not installed in university, such as Civil 3D and Infraworks. With all these software, how do the students or even the teaching faculty know which software the future landscape architect should learn?

Currently software teaching at the Architecture Department is based mainly on online video tutorials, meaning that learning 3D modeling is more self-sufficient than before. This means more freedom for students in software learning - but also requires more knowledge on the student’s part on which software they want to learn.

2.2. Research goals

This study intends to serve as a guide for those landscape architects looking to start learning new 3D modeling software. The objective is to provide information of what 3D modeling is currently capable of and what it is not capable of to prospective 3D modelers. Through exploring the possibilities and limitations of 3D modeling, ways that readers can better use 3D modeling can be considered.

Some of the possibilities of 3D modeling are:
- reducing design errors
- giving better understanding of the project
- better landscape architecture designs
- streamlined design process, reducing unnecessary manual work

Some of the limitations with 3D modeling are:
- technical issues related to specific software
- multitude of software makes it difficult to choose which software to focus on
- certain aspects of 3D modeling are too difficult or time-consuming

There may be a discrepancy between what benefits are desired from 3D modeling, and which are actually achieved. For example, 3D modeling is desired to simplify the design process, but due to current software limitations, it may actually make it more complex [1]. This depends on the software and design at hand: Some software programs are easier to use than others - but on the other hand, they may lack in other features that the designer desires [2]. This is why the features and limitations of 3D modeling must be looked at in several different software, as some of them are software-specific.

Some research has already been done of the benefits and limitations of 3D modeling in general, as is discussed in the literature review. But there have been no studies that compare the benefits and limitations between certain software. Are the benefits and deficits applicable to all 3D modeling or only certain software? And which of the software has the most benefits for landscape architecture at the moment?

The findings from this study can be used to help decide which 3D software to use in landscape architecture, as well as a guide for software designers on how certain software could be improved landscape architecture in mind. Some work has already been done on making a prototype of a landscape information modeling software (Gill, 2013) . However, there are also opinions that landscape architecture is a too small profession to demand new software and instead, quick fixes and workarounds in current software should be considered (Sipes, 2014) . This study can provide a starting point for such considerations.

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1 The survey (full results found in appendix) with Finnish landscape architects found that only 4% thought a design with 3D modeling took less time. The reason mentioned was that being able to make 2D drawings from the model could make the work process more efficient and less time-consuming. Contradictorily, it was also commented that 2D drawings alone were enough and faster to make, and this is why an additional 3D model made the process slower.

2 For example, according to the results of the survey, Sketchup is thought to lack in features but have a simple modeling process, whereas eg. Rhino has a more complex modeling process and more features.

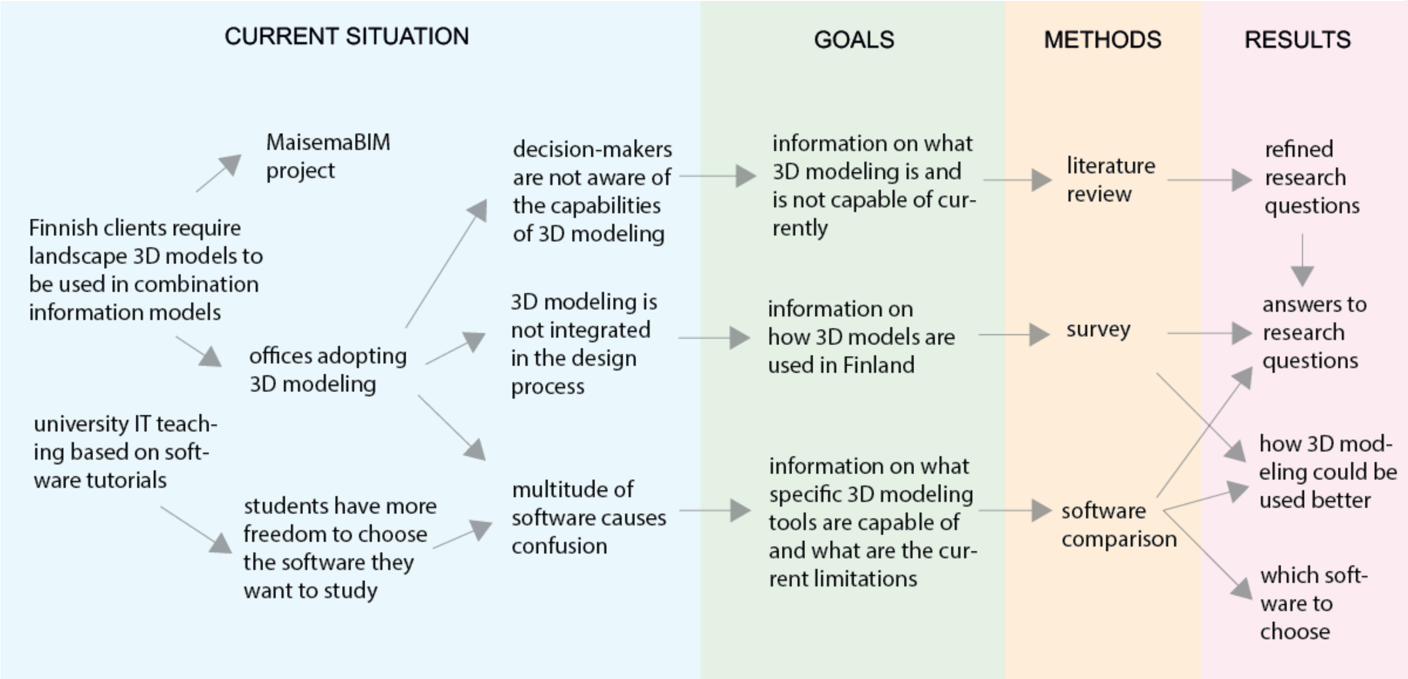


Figure 2. Depiction of how research goals and methods are formed.

2.3. Thesis organization

The introduction chapter describes the current situation of 3D modeling in landscape architecture in Finland and the problems relating to it. From these problems, the research goals are formed, as shown in the above chart. The different research goals are approached with corresponding methods. These methods are a literature review, a survey with Finnish landscape architects and a software comparison. The methodology of each method is explained in more detail in the corresponding chapters of the thesis.

The first method used is the literature review. This gives an overview of state-of-the-a capabilities and limitations of 3D modeling in general. The literature review also helps to refine the research goals of the thesis into more specific research questions by revealing the knowledge gap in the existing literature.

The second method used is the survey performed with Finnish landscape architects and students. This relates the scene at Finland to the overall trends in landscape architecture 3D modeling found in the literature review, giving light to the specific problems present in Finland. The survey can answer some questions arising from the literature review. The relevant findings are discussed in the findings section, the full results of the survey are included in the appendix.

The third method is the software comparison, which is used to specify the features and limitations of specific software, and compare these to each other. The specific limitations can be used to consider strategies to improve them. The reflections of the software comparison give guidance on how to choose a suitable software, and what relevant parties can do to improve the state of 3D modeling landscape architecture in Finland.

The reflections produced by each method are integrated in the chapter that concerns the method used. In the final conclusions it is considered how well the research questions of the thesis are answered.

If you are interested in which 3D modeling software you should choose, you can skip to the software comparison reflections. If you wish to learn more about the differences of the software in specific tasks, you can check the findings of the software comparison. If you want to use the comparison as a guide on how to use a certain software, check the manuals and tutorials as well. Links to software manuals are included in the appendix. Terminology of 3D modeling types is also found in the appendix.

If you are interested in how landscape architects in Finland use 3D modeling, check the findings of the survey. If you are interested in what other studies say about this subject and the more specific research questions of this thesis, read the literature review.

3. Literature review

3.1. Methodology

The goal of this study is to find out how 3D modeling can be improved and be more efficiently utilized as a part of the design process. In order to do this, the deficits and benefits of 3D modeling must be considered. A literature review is conducted to provide knowledge on the current capabilities and limitations of 3D modeling. The literature review also helps to refine research questions by articulating the knowledge gap in landscape architecture 3D modeling literature, thus giving insight into how this study can contribute to the field of research in landscape architecture. According to the book “Research methods for architects” (Groat & Wang, 2013), finding a gap in the literature is one way to frame a research question. However, when this method is chosen, finding sources for your work becomes a problem.

The search process started by looking at the proceedings of Digital Landscape Architecture Conference. Keywords found in these papers were used in subsequent searches on websites that publish research papers (e.g. ResearchGate) ang Google Scholar searches. The sources of found papers have also been used. Additionally some papers were found by looking at the related literature of already found sources on ResearchGate.

The papers were selected to give an overview of studies that have been conducted on the benefits and limitations of landscape architecture 3D modeling. The found studies are divided into those that relate to landscape architecture and digital tools in general, 3D modeling specifically and BIM. Other references that relate to benefits and limitations of 3D modeling were found, but were excluded due to not providing sufficient proof for their claims. The selected literature make use of surveys and experiments that were evaluated by author to provide valid results for the purposes of this literature review.

After pinpointing the most relevant articles for this study, summaries of their most relevant findings that relate to landscape architecture 3D modeling are provided in the literature review. At the end of each article, a bullet point list is provided on the research questions that were explored in the article. In the bullet point list it is outlined:

- which research questions are studied
- which research questions are not answered in depth
- which research questions are not studied at all

The unanswered research questions give an idea of the knowledge gap, which is articulated in the reflections of the literature review. The knowledge gap can then be further answered by conducting a survey as well as conducting a software comparison using example design tasks.

3.2. Findings

3.2.1. Digital tools

Digital tools in Landscape Architecture

The article “Digital tools in Landscape Architecture” analysed the use of digital tools in landscape architecture in Latvia in 2017 (Ņitavska & Mengots, 2015). The results were gathered with a questionnaire and showed that all the surveyed landscape architects used digital tools in their everyday professional practice. Tools used were mainly CAD, image processing and 3D modeling. GIS, virtual reality and BIM tools were not widely used. There were some factors limiting the use of some digital tools: software prices were said to be too high compared to market prices in Latvia, and there was also a lack of skills in handling the digital tools available.

A survey on the effectiveness of different visualization types was also conducted. The results of the survey showed that technical drawings did not fully allow the residents to get an idea of the project, but that 3D visualizations – animation and the interactive 360° panorama were more useful. For professionals the technical drawings were equally easy to understand, but they acknowledged that using both 2D and 3D together showed the most complete information. It is notable that the 3D visualizations were more easy to understand to both residents and students.

In the conclusions the deficits of current digital tools are discussed. The paper states as a deficit the lack of specially designed tools for landscape architects in 3D modeling - underlining the lack of plant libraries and stating that modeling of the terrain and the integration of objects in it is too complicated. The study also underlines the lack of specific BIM software for landscape architects.

Main findings:

Studied:
- Use of digital tools in Latvia in 2017
- Percentage of usage (85%)
- Tools used (CAD, image processing, 3D modeling)
- Limitations to using digital tools (high prices, lack of skills)
- Readability of 2D vs 3D visualizations (3D is more readable for laypeople and students)

Discussed:
- Deficits of 3D modeling (lack of tools for landscape architects)

Not studied (knowledge gap):
- Use of digital tools in Finland in 2018
- How digital tools affect the design process in terms of time, efficiency and creativity
- How digital tools affect design costs. (Digital tools are said to have high costs but how does it play into the overall budget?)
- How digital tools affect the design results
- Other considerations between digital vs. analogue tools

Digital vs. analogue tools

On digital vs. analogue tools, according to the article "New tools - Digital media in landscape architecture" (Nijhuis, 2013) "digital media such as CAD, GIS, 3D modelling and image-processing software can be seen to function as an 'extension of the hands', where a pen and pencil are replaced by a mouse and digital drawing pen". Likewise "using the calculating power of computers, combined with inventive analysis, modelling and visualisation techniques, [the computer] creates new information and knowledge about spatial construction, processes and use. In this context, digital media can be seen as an 'extension of the brain', as tools for supporting observation and reflection."

"It is not that digital media replace analogue media – they are complementary. They both belong in the toolbox available to landscape designers and researchers. Each tool, whether digital or analogue, has its own qualities: hand-drawn sketches and models are just as important as computer-generated information or virtual 3D landscapes."

When it comes to the discussion between analogue and digital tools, both sources ("Digital tools in Landscape Architecture" and "New tools - Digital media in landscape architecture") seem to agree that they can complement each other. According to the first study, 3D and 2D combined create a fuller image of the project. The second writer provides rhetorics to support the idea that digital and analogue tools complement each other, but no quantifiable data to back it up.

All in all, it can hardly be argued that the combined use of all the tools that are available can create the best design results. But what remains unanswered is how the plurality of both analogue and digital tools affects the design process in terms of time, efficiency and creativity. In what ways precisely do digital and analogue methods complement each other? What is an example of a case when digital/analogue is better?

Main findings:

Discussed:
- Are either digital or analogue tools better than the other? (No, they complement each other.)
- How using digital+analogue tools affects the design results (Probably better.)

Not studied (knowledge gap):
- How does the plurality of both analogue and digital tools (using various analogue and digital tools together) affect the design process in terms of time, efficiency and creativity?
- In what ways precisely do digital and analogue methods complement each other?
- In which cases is digital/analogue better?

3.2.2. 3D modeling

An Evaluation of Current Applications of 3D Visualization Software in Landscape Architecture

“An Evaluation of Current Applications of 3D Visualization Software in Landscape Architecture” is a Master’s thesis that attempts to identify trends, opinions, and barriers to applying 3D visualization software in the field of landscape architecture in USA (Jie Yan, 2014). A questionnaire was supplied to landscape architecture professionals in the United States. Overall, the respondents appeared to have made limited use of 3D software. Only 30% of the respondents said they often or very often used 3D software during the landscape design process.

The aims of the study:

- to produce quantifiable data on 3D software use in the profession
- educators in the field will be able to incorporate insights from the study into curriculum design and course development
- 3D software developers will be able to use the information to improve existing software and create new programs better suited for landscape architecture

The most popular 3D software used by all educational levels in United States in 2014 was Google SketchUp. Among the 3D software programs listed in the survey, respondents indicated that Google Sketchup, ArcGIS, AutoCAD Civil 3D, 3D Studio Max, and AutoCAD Map 3D were most utilized. With all the 3D software programs covered in the university courses, the top five taught in landscape architecture were: ArcGIS, Google Sketchup, Rhinoceros 3D, AutoCAD Civil 3D, and 3D Studio Max. There were some differences in what was taught in universities vs. what was used in offices. A large difference was in the use of Rhinoceros 3D, with 13% of professional use, compared to 61% of educational use. Google Sketchup was almost equally used in both, with 93% of offices using it, compared to 86% of universities.

The study notes that a debate on what are the core 3D software programs exists and that there is no consensus on what 3D visualization software should be taught - rather it varies by teacher and university. The author speculates that if the teacher is an expert on certain 3D software, he/she would possibly teach this 3D software in lieu of others. Otherwise, faculty members would have to commit themselves to ongoing training in order to keep pace with the rapid software changes, requiring extra costs and resources from universities. Additionally developing a new course would need a substantive amount of work.

The study identified several constraints on the future growth of 3D visualization software. Findings from the study suggested that 79% of the respondents were dissatisfied with the longer time that they spent on generating 3D models rather than 2D methods. The high price of the 3D software, the difficulty of learning the software, and low desirable rendering quality were other challenges that impeded the application of 3D visualization tools in the landscape architecture profession. There are also concerns by professionals that the tendency of developing more and more pre-set models or templates in 3D software could lead to having more and more similar design projects.

According to the study, new 3D software development is desired by landscape architecture professionals for particular benefits it can bring to their work, such as reducing time for various tasks, simplifying the software learning process, and rendering photorealistic images. Over 50% of professionals cited: a simplified learning process, lower investment cost, a more realistic representation of plants, larger texture libraries, and better rendering quality. An average of 30% of the respondents expressed a strong agreement on increasing efficiency of navigation/orientation tools, providing easy internet presentability, improving interactivity with client/general public, shortening the simulation process and improving interoperability. (Figure 17).

The study focuses on 3D modeling mainly in a visualization point of view rather than as a part of the entire design process. In his literature review, the author refers to a criterion for evaluating the overall landscape visualization quality that was designed by Sheppard and Cizek (2009) . The criterion established six visualization quality categories: accuracy, representativeness, visual clarity, interest, legitimacy and access. He also refers to the research conducted by He & Thompson (2011), which states that the increase in detail helps eliminate ambiguity and increase the validity of visualization results. Based on his references, a more detailed and realistic visualization would be most helpful for professionals - and according to the survey, the professionals seem to agree.

Main findings:

Studied:
- Use of 3D modeling software in United States in 2014
- Percentage of usage (30% often / very often)
- Software used (Google Sketchup, AutoCAD Civil 3D, 3D Studio Max)
- Differences between software use in offices vs. universities (universities use Rhinoceros 3D in 61% of courses compared to 13% of offices)
- How 3D modeling affects the design process in terms of time (most people felt 3D modeling takes longer than 2D methods)
- Limitations to using 3D (high price, time, low rendering quality, difficulty of learning)
- What landscape architecture professionals consider important regarding future development of 3D software (reducing time for various tasks, simplifying the software learning process, rendering photorealistic images)
- What is important for visualization quality (accuracy, clarity, detail)

Discussed:
- Reasons behind the differences between software use in offices vs. universities (personal preference by teachers, resources)
- Pre-set models or templates in 3D could lead to decreased creativity

Not studied (knowledge gap):
- Use of 3D modeling software in Finland in 2018
- What in particular causes professionals to feel like 3D modeling takes longer than 2D methods?
- Does 3D modeling actually take more time than 2D methods?
- How 3D modeling affects the design process in other ways in terms of creativity
- How 3D modeling affects design costs (3D modeling software are said to have high costs but How does it play into the overall budget?)
- How 3D modeling affects the design results
- How different 3D modeling software differ from one another in all the ways described above

Visualizations

Emphasizing the benefits of 3D visualizations, 3D can be said to be revealing - the same things that work in 2D do not necessarily work in 3D. According to Landscape Architecture : An Introduction (Holden Liversedge, 2014): “Reality is three-dimensional and two-dimensional plans undertaken without an appreciation of the third dimension can lead to flat design: designs that appear strong from above may be ineffective at ground level.” Indeed when the focus is on 2D plan drawings, the aesthetics of the plan drawing can be unnecessarily emphasized.

According to a case study by Sunesson et al. (2008) professionals felt that realistic 3D models in VR were too exposing of the design’s flaws. This study was about exploring 3D models in VR in particular, but many software such as SketchUp already include ways to experience the model that is similar to VR - by virtually walking around on the ground surface - so arguably the results of the study can be extended to 3D models in general. Exposing the flaws of the design via a 3D model may not feel comfortable to the designer, but is to the benefit of the design quality.

Main findings:

Studied:

- How does 3D modeling benefit landscape architecture (Professionals feel that certain ways of viewing a 3D model are more revealing of a design’s flaws than 2D drawings)

Not studied (knowledge gap):

- Do 3D models actually lead to better designs?

3.2.3. Landscape Information Modeling

Integrating BIM Technology into Landscape Architecture

According to the document "Integrating BIM Technology into Landscape Architecture"(Sipes, 2014) 3D modeling differs from BIM in that 3D modeling tools generate 3D representations of geometric data, but these objects do not have any intelligence attached to them. BIM refers to Building Information Model, meaning the building information is attached to the 3D model. It is important to note that according to this source the word "building" in BIM refers to a verb and not a noun, so it is referring to the building process, not just an architectural building. Taking this into account, BIM can include both Land Information Models (LIM) and Site Information Models (SIM).

The paper emphasizes that BIM is more about process than it is about a certain software. BIM is just a container for data, and the transfer of that data is what is important. That is why largely the paper deals with information exchange - that is the file formats for exchanging data between software. Some of the more notable file formats in use are IFC and LandXML.

Benefits of BIM:
- It allows you to create a virtual version of a building before it has to be constructed physically - less waste of materials and time; less reworking
- Information flows from phase to phase and from discipline to discipline without the need to re-enter data - reduced errors and omissions, fewer translation errors and losses
- Better understanding of design concepts - shared understanding of issues between different disciplines
- Less time spent on unvaluable tasks - more focus on value-added tasks

Obstacles to using BIM:
- Poor software interoperability: The standards for how information should be formatted for exchange are still a work in progress.
- Most BIM file standards don't recognize landscape elements: There is no industry standard for how to define a tree or vegetation and such BIM objects do not exist. This means that the 3D objects created by many landscape architects are primarily visual representations of objects.

The source states that landscape architects should be involved in developing BIM, because otherwise architects and engineers may take their place in a BIM project - and in defining the BIM landscape elements and standards. The paper states landscape architects need to think both in terms of how BIM can be used in the short term and expanded in the long term. It is noted that some believe that landscape architecture is too small a profession to influence how software is developed - so landscape architects should think of other solutions. In the short term most programs provide the option to customize existing BIM tools to meet immediate needs. This may involve being creative with using the tools in Revit or other BIM software, or it may involve working with more traditional landscape design software that is able to import/export IFC, COBie, or other BIM formats.

According to this paper, most BIM software were not at the moment of writing yet capable of handling landscape design to a degree that would make them a worthwhile investment for a landscape practice and buying a particular software over another would not enable a landscape architect to work more effectively than they can do without that software. However, many firms were reported to work with programs such as Vectorworks, Autodesk Civil 3D, or SketchUp and then exporting files using an IFC format.

Main findings:

Studied:

- Projects that used BIM
  - which software was in each project
- BIM file formats (IFC, LandXML, etc.)

Discussed:

- BIM software (several are used, but none in particular can be recommended over the others)
- Benefits of BIM (efficiency and communication)
- Obstacles to using BIM (poor software interoperability and file formats)
- Definition of BIM (The exchange of information is central, building in BIM refers to the act of building.)
- Definition of BIM/LIM (LIM is a subtype of BIM.)
- What landscape architects can do to improve BIM (Tweak software.)

Not studied (knowledge gap):

- What are the advantages/disadvantages of each BIM software?
- What are the benefits of a certain software combination over another?
- How in particular could each software be tweaked?
- Desired features for a LIM software

A 3D landscape information model - using real-time 3D graphics for site-based landscape design

“A 3D landscape information model - using real-time 3D graphics for site-based landscape design” (Gill, 2013) is a doctoral dissertation in the Department of Computer Science, University of Sheffield, that created a LIM prototype and studied some features that would be desirable for such a software. It was studied with a hands-on experiment that there is a preference for both 2D plan and interactive 3D walk-throughs, so it was concluded that they should include both mapping and a 3D walk-through mode in the interface. They also concluded the degree of realism should be able to be adjusted according to the stage of the design - less realistic for more early stages. Switching between versions of design and spatially highlighting areas of difference between two versions were also deemed to be desirable features.

Relating to the work process, it is suggested that with any response over two seconds there can be a detrimental effect on the train of thought of a user, so faster calculation times are desired. Another way to reduce the time to create models of landscapes was by using procedural modeling with a library of suitable 3D models. It was noted the terrain modeling used in the prototype was too difficult and should be improved - perhaps through controlling terrain modification through a set of parameters and the procedural generation system.

In simulations, cost calculation, Envi-Met microclimate simulations, flood simulations and agent based modeling for the behaviour of pedestrians was tested. A future consideration suggested by the study was having the software itself as a designer: the computer would produce multiple designs and then pick the elements that perform better than others.

Main findings:

Studied:
- interface preferences
- the technical specifics of how to build a new LIM software

Discussed:
- desired features for a LIM software

Not studied (knowledge gap):
- how current BIM software could be improved

3.3. Reflections

3.3.1. Known benefits and limitations

According to the sources used in the literature review, 3D modeling can potentially benefit landscape architecture in the following ways:

1. Several studies state that 3D visualizations are more readable than 2D visualizations for non-professionals - thus they improve communication of the design.
2. A more realistic and detailed visualization combined with the right display method can be useful for professionals in revealing the design errors.
3. BIM allows to create a virtual version of a design before it has to be constructed physically, which means less errors and less waste of materials and time.
4. The information in BIM allows shared understanding of issues between different disciplines and better understanding of design concepts.
5. BIM allows information to flow without re-entering data, so less time is spent on unvalued tasks and more on value-added tasks.
6. Simulations such as flooding and microclimate simulations would allow landscape architects to better evaluate the impacts of their design before implementation.

Potential limitations in 3D modeling were identified in the literature review:

1. 3D modeling is considered to be slow and difficult
2. 3D modeling software are considered to be costly
3. some 3D modeling software are considered to have low rendering quality
4. 3D modeling could negatively affect creativity if more and more preset templates and models are used

3.3.2. Knowledge gap

Many sources state that current 3D modeling software are lacking in applications to landscape architecture, and new 3D modeling software development is desired. The development of such a software is explored in a study made by the Department of Computer Science in the University of Sheffield in 2013. However, a paper by the American Society of Landscape Architects states that landscape architects are not able to demand development of a new software, so short-term solutions should be focused on instead: tweaking existing software. However, the ways to tweak the existing software have not yet been studied. It is also agreed that there is no general consensus on which 3D modeling software currently is better for landscape architecture. However, no studies comparing the advantages and disadvantages of each software has been made, so there is no basis on which to make such a conclusion.

Main knowledge gaps:

- How do all the current 3D modeling software compare to each other?
- How can these software be “tweaked” for landscape architecture?

Other gaps in knowledge detected by the literature review that are relevant to this study:

- Use of 3D modeling software in Finland in 2018, including statistics and opinions of professionals on the benefits and limitations of 3D modeling
- Potential benefits and deficits of 3D modeling

Potential deficits of 3D modeling:

- How 3D modeling affects time expenditure in the project - does 3D modeling actually take more time than 2D methods? What in particular causes professionals to feel like 3D modeling takes longer than 2D methods?
- How 3D modeling affects design costs (3D modeling software are said to have high costs but how does it play into the overall budget?)
- How 3D modeling affects the design process in terms of creativity

Potential benefits of 3D modeling:

- Professionals feel that 3D visualizations are more revealing of a design’s flaws - but do 3D models actually lead to better designs?

3.3.3. Research questions

From the knowledge gap, the actual research questions for the thesis are be defined:

1. Use of 3D modeling software in Finland in 2018
- Who does landscape architecture 3D modeling in Finland and who doesn't? Why?
- How much are 3D models used as part of the design process?
- In what ways are 3D models used?
- What kinds of projects are 3D models used for?
- Which software are used in 3D modeling?
- Which benefits are desired from 3D models?
- Which benefits are gained from 3D models?
- What prevents Finnish landscape architects from taking full advantage of 3D modeling?

3. What are the deficits in 3D modeling currently? What prevents 3D modeling from being taken full advantage of?

How do 2D and 3D processes relate to each other in terms of time management?
- Does 3D modeling increase the time spent in the design process?
- Is 3D modeling viewed as an additional burden in the design process?

How does 3D modeling affect design costs?
- Cost of the software + time spent on 3D modeling
- Is 3D modeling viewed to raise the design costs?

How does 3D modeling affect the design process in terms of creativity?
- Is it viewed to decrease creativity?

4. How could these deficits in 3D modeling be improved?
- Reducing the time spent on 3D modeling
- Exploring how the software tools affect creativity and what kind of a modeling process would increase creativity
- Comparing how well the current 3D modeling software qualify against each other in terms of the desired benefits and undesired deficits
- How the detected deficits in software could be improved

5. How well do the current 3D modeling software qualify against each other?
- Which software could be recommended for which task?
- Is there any software that can be recommended over others overall?
- What could be done to improve the detected deficits?

3.3.4. Contribution to the field

There has been no study so far comparing the various 3D modeling software for landscape architecture. Instead, there is a mixture of different approaches with each office, institution and landscape architect using their own preferred software, with no general consensus of which is best for which purpose. There is currently no scientific data available to back-up the choice of each software, rather the choices are made based on recommendations, guesswork and what professionals are already familiar with. This could potentially lead to faulty software choices.

In the literature review, some deficits in 3D modeling have been found - but it has not been studied whether these deficits, such as wasted time, higher costs and lower rendering quality, affect only certain software. As well it has not been studied which software have the highest benefits for landscape architecture.

This study aims to find if certain benefits and deficits of 3D modeling apply only to certain software. This helps to further specify the actual benefits and deficits of 3D modeling software for landscape architects at the moment. It also helps professionals make better choices in which 3D modeling software to use. Software-specific deficits can also be used as guidance in improving the software themselves.

The information gathered from the survey will be used to contribute to this purpose by gathering software specific as well as non-software specific information on gained and desired benefits as well as perceived limitations. The information on which situation 3D models are used and how well, can be used to decide whether a 3D model can provide benefits for a certain task. The software comparison can provide information on which software can be best utilised for which task.

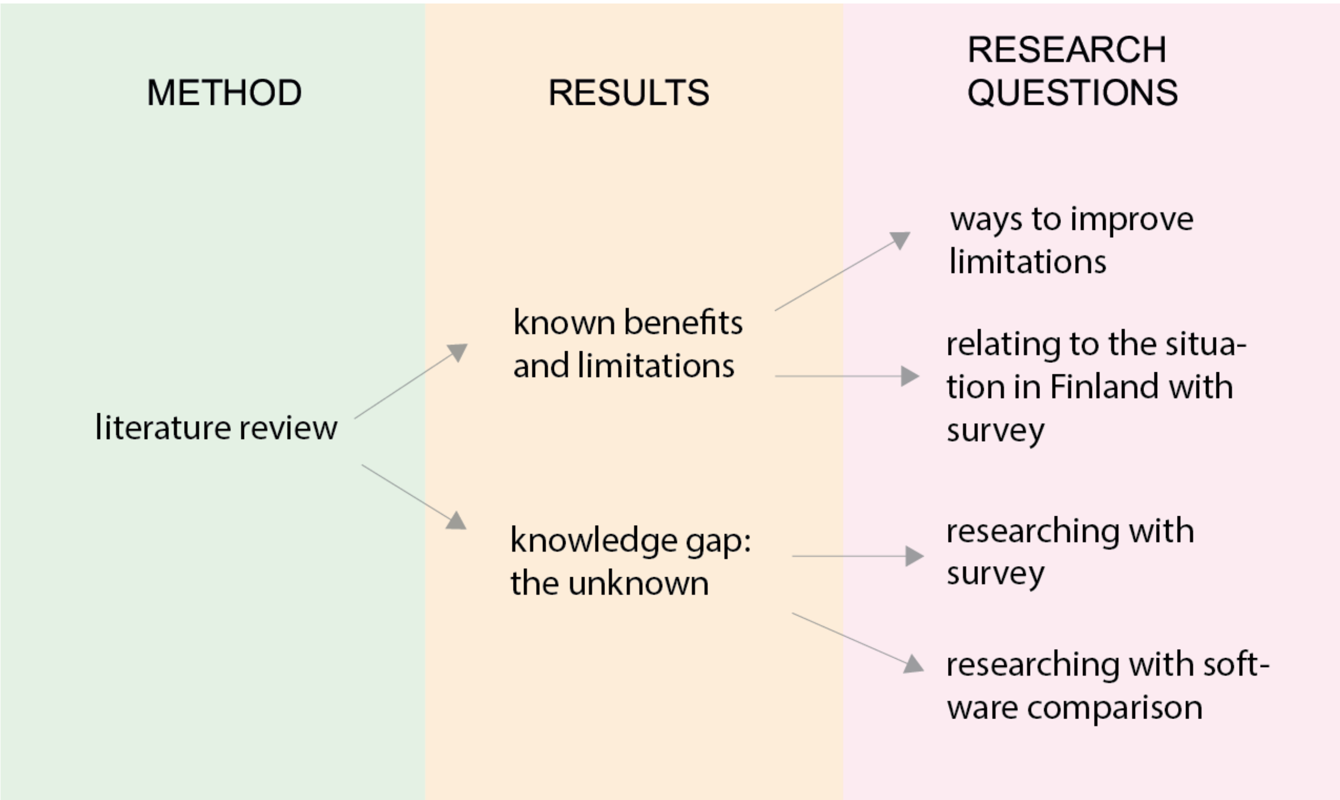


Figure 3. Depiction of the role of the literature review in the thesis.

4. Survey

4.1. Methodology

To gain context on how 3D modeling is utilized in Finland, a survey is performed with Finnish landscape architecture professionals and students. The information gained is used to consider if and how the situation could be improved.

The information is gathered using a survey, because according to “Constructing questions for interviews and questionnaires - theory and practice in social research” (William Foddy, 1993) asking questions is a cost-efficient and sometimes the only way of gathering information about past behaviour, private actions, values and attitudes. These are considered subjective variables that cannot be measured directly - for objectively measured variables other research methods would be more useful.

There are other potential problems as well that must be taken into account in completing a survey According to Foddy (1993), some of the problems are:

- Factual questions sometimes elicit invalid answers. Sometimes the answers given can be proven to be incorrect. This can be attributed to a lack of effort on the respondents’ part or simply the limits of human memory.
- The relationship between what respondents say they do and what they actually do is not always very strong. The respondent may feel threatened by a question, and respond in a way that they believe is more desirable, rather than with how they actually behave.
- Respondents commonly misinterpret questions as well as other rhetorical concerns:
    1. Small changes in wording sometimes produce major changes in the distribution of responses
    2. Answers to earlier questions can affect respondents answers to later questions
    3. Changing the order in which response options are presented sometimes affects respondents’ answers

Considering the limitations of a survey, it must be considered which research questions can actually be answered with a survey, and to what extent - and which questions may warrant additional research. In order to get valid results from the survey, the wording of the questions must be paid additional attention to. According to Foddy (1993), criteria for a good questionnaire are:

- only necessary questions are asked
- questions are worded in an understandable manner and with clear terminology
- questions must be related to the research objectives of the study

It can be considered that with a large enough sample size, the survey may provide accurate information on the following questions:

- Use of 3D modeling software in Finland in 2018
- Who uses it?
- How is it used?
- How much is it used?
- What is it used for?
- Which software are used?
- Does software use vary depending on being a student/professional?

However, the information found with a survey on the following questions may be more approximate (it must be remembered that the results are subjective rather than objective - more reflective of the feelings and opinions of respondents than the actual reality):

- Does 3D modeling increase the time spent in the design process?
- How does 3D modeling affect design costs?
- How does 3D modeling affect the design process in terms of creativity?
- How does 3D modeling affect the design results?

More valid results would be found with quantitative research on some of the questions. To find information about time use, data from companies about the software costs and payroll hours could be gathered directly. Comparison of design results would require finding sample projects that a) made use of 3D modeling and b) did not use a 3D model - and evaluating them against each other in terms of completed design quality. However, this additional research is not doable within the limits of this study, so the subjective views of landscape architects are relied upon instead.

The survey was sent out at 19.11.2018 and a reminder was sent at 1.12.2018. The survey closed at 17.12, four weeks after it was first opened. The survey was provided in both Finnish and English. Most replied in Finnish, however the English translation will be used in this study whenever possible. Freeword answers in Finnish will be included as part of the full survey results in the appendix.

The survey was sent to:

- Aalto university's landscape architecture students' mailing list
- The mailing list of student organization Vista ry
- All Finnish landscape architecture offices that were listed in the yearly publication "Vihreä kirja". Offices listed in the past five years of publications were used.
- Members of the Finnish landscape architecture organization, listed in the newest Vihreä kirja.

In total the survey was sent to 370 individual email addresses. However, some of the email addresses may be duplicates or owned by the same person.

The amount of recipients on the student mailing list is currently unknown. On the Vista mailing list there are 175 recipients - however, a majority are also on the other mailing lists.

The total amount of individual email addresses included in the survey is estimated to be 300-500. The survey had 73 respondents. Thus the response rate is estimated to be 10-20%.

The respondents were asked whether they had done 3D modeling

- during studies
- at work
- by a team they were leading
- never

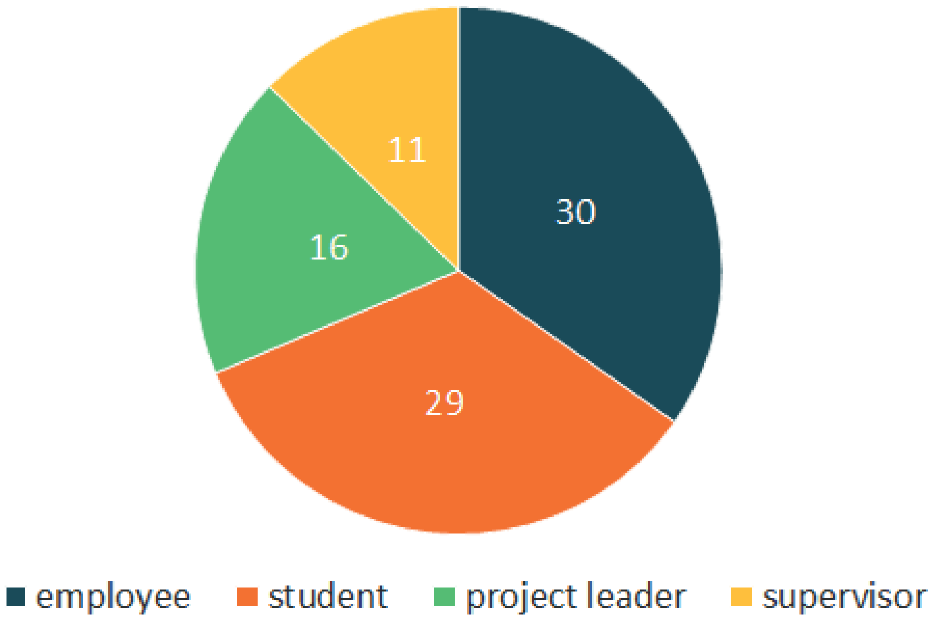
More than one option could be selected. The answers to this question decided which questions were shown afterwards. If experience during studies or work was selected, questions pertaining to 3D modeling in general as well as personal 3D modeling experience were shown. If team experience was selected, questions pertaining to 3D modeling in general were shown. If no experience was selected, only questions pertaining to the no experience group were shown. This is to ensure that only relevant questions were presented to each group.

The results of the survey are presented and analysed through the lense of the main research goals. The most relevant and conclusive results are presented in a qualitative manner in the Findings chapter. Full results are included in the appendix.

4.2. Findings

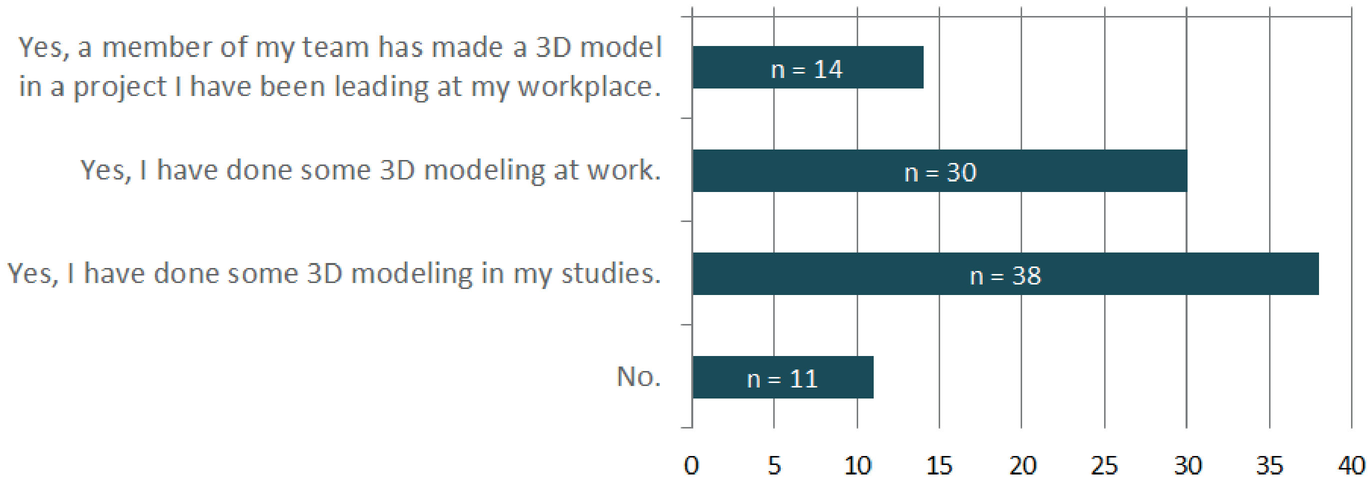
The survey had 73 respondents, 30 indicating they were an employee, 29 students, 16 project leaders and 11 supervisors.

Professional status of those who responded to the survey
Number of respondents: 73, selected answers: 86



Out of 73 respondents, 38 replied that they had done some 3D modeling during their studies, 30 replied they had done 3D modeling at work, and 14 replied that a member of their team had made a 3D model in a project they had been leading at the workplace. The options selected in this questions decided which questions were shown next.

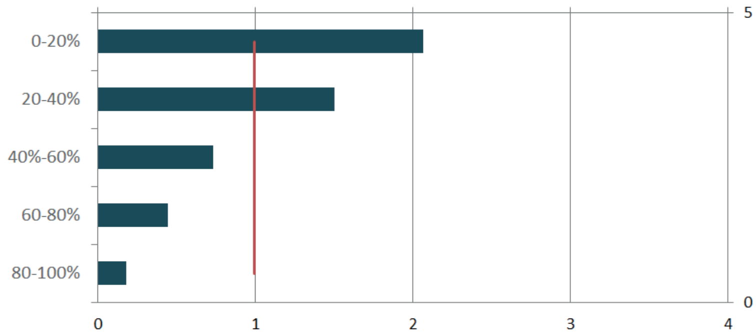
Have you ever made use of a 3D model in a landscape arChitecture project?
Number of respondents: 73, selected answers: 93



4.2.1. How 3D models are used

Of those that had personally done 3D modeling (47 respondents), 55% estimated they spent at least 20% of their time in a design task on 3D modeling at least sometimes.

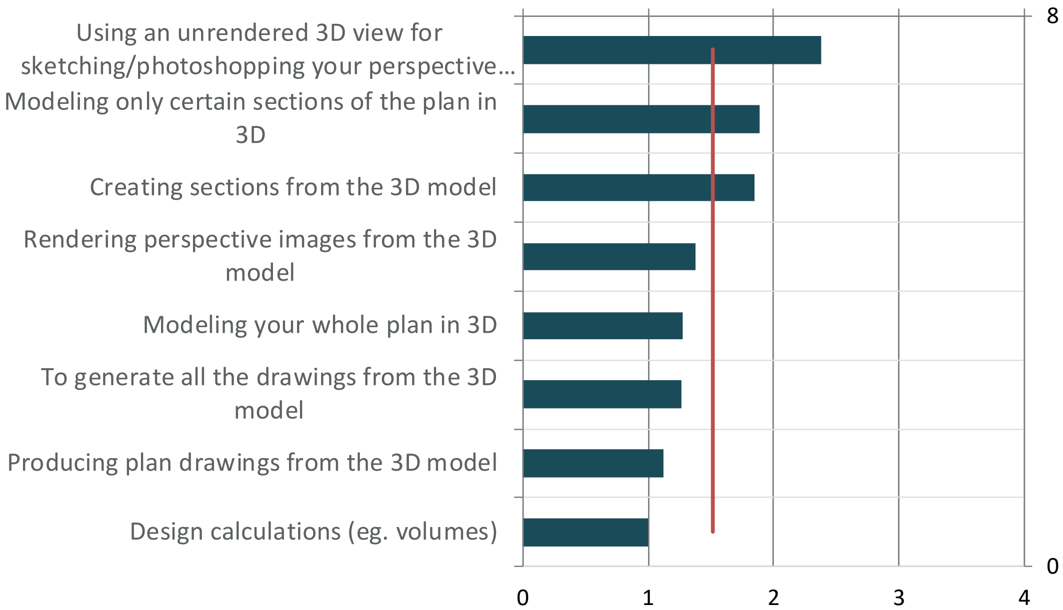
How often do you estimate the following percentage of time in the design process is spent on 3D modeling in your design projects?
Number of respondents: 47
0=Never, 4=Always



	≥ Rarely	≥ Sometimes	≥ Often
≥20%	64%	55%	42%
≥40%	32%	23%	23%
≥60%	14%	11%	10%

3D models were most often used for sketching a perspective view on top of a view printed from a 3D model. Modeling parts of a design and creating sections from the 3D model were the next most common forms of use.

How often have you used 3D modeling as a part of the design process in these ways?
Number of respondents: 52
0=Never, 4=Always



In the free-word question of what kind of projects 3D modeling is used for, 3D models were most often used during studies, in yard / park planning and city planning. Doing 3D modeling during studies but never at work was commonly mentioned.

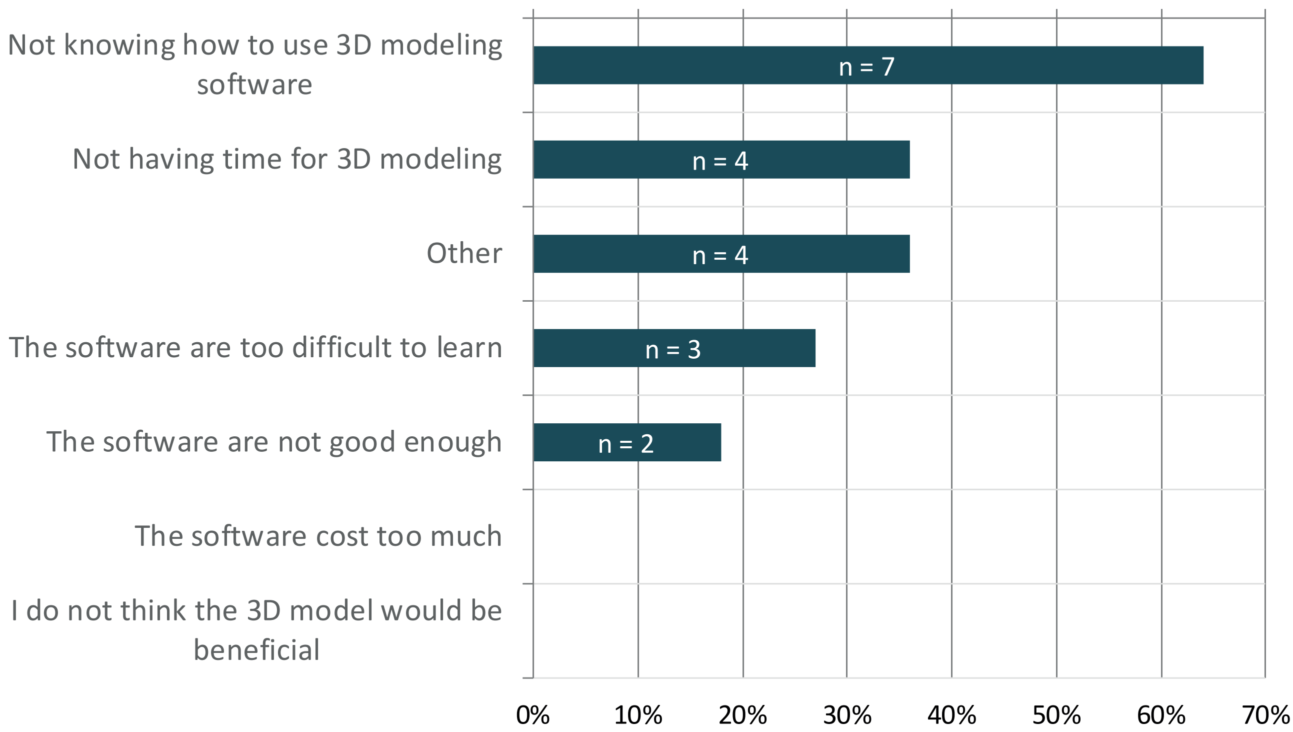
4.2.2. Who doesn’t use 3D models and why

Out of the 73 respondents, 11 stated that they had never in any way made use of a 3D model in landscape architecture. Of these 4 were students, 4 employees, 3 project leaders and 1 supervisor.

Did not use a 3D model	student	employee	project leader	supervisor
Number	4	4	3	1

Overall 15% of respondents had never made use of a 3D model either themselves or by a member of a team they were leading. As the reason why, “Not knowing how” was selected by majority, 7 respondents (64%). A responding student indicated that they had not yet had time to start a 3D modeling course in their studies in the free-word section. Other reasons selected by respondents were “Not having time for 3D modeling” (4 respondents, 36%), “The software are too difficult to learn” (3 respondents, 27%) and “The software are not good enough” (2 respondents, 18%). Other free-word reasons were stated as clients not having interest, and not having any software available when they were actively doing landscape architecture.

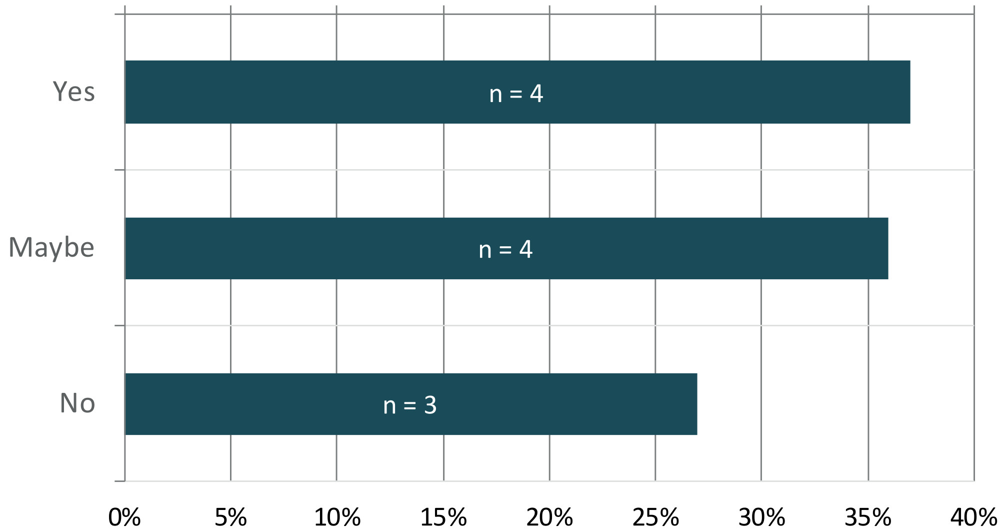
18. What are the reasons you have not used a 3D model in a landscape architecture project?
Number of respondents: 11, selected answers: 20



The cost of software and not considering 3D modeling beneficial were selected by none of the participants. From this it can be concluded that Finnish landscape architects consider 3D modeling to be beneficial, but not having the skills to use the software can be an obstacle, along with not having time to acquire the skills. Some also think that the software themselves are too difficult to learn or not good enough.

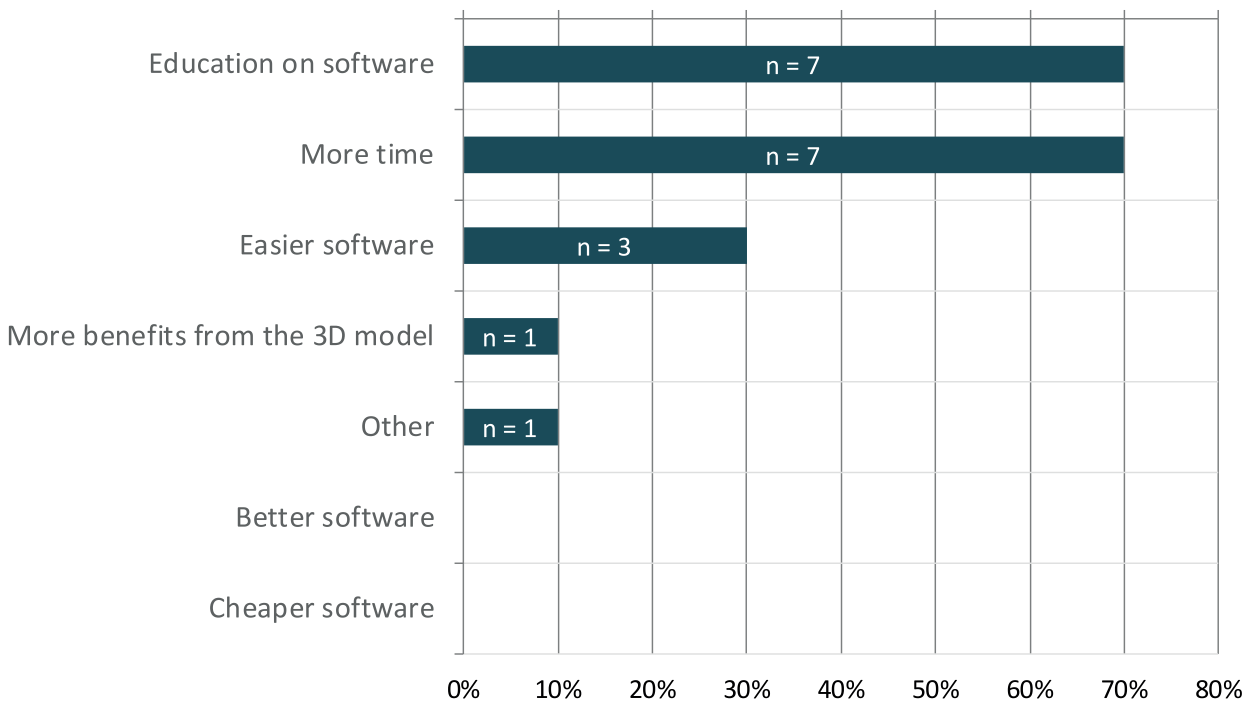
Out of 11 respondents, 4 said they would like to use a 3D model in the future, 4 said maybe.

Would you like to use a 3D model in the future?
Number of respondents: 11

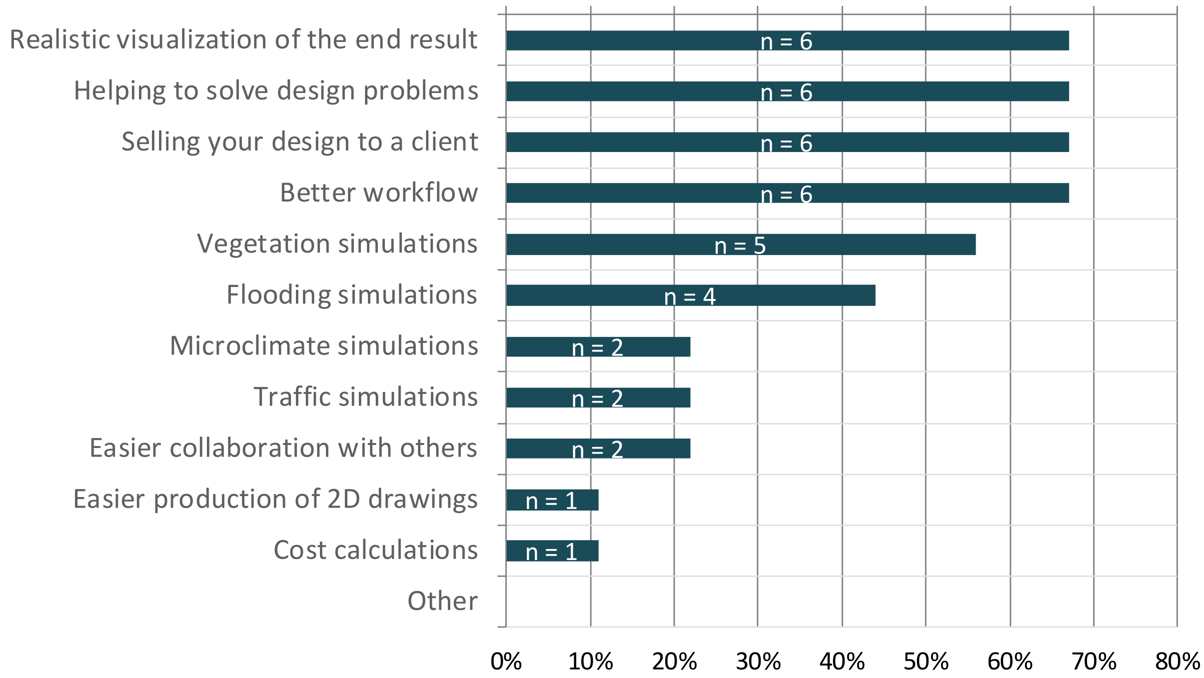


Out of 10 respondents, 7 said education on using software as well as having more time to learn the software was required for them to make use of 3D models in the future. 3 respondents selected “Easier software” as a criteria for doing 3D modeling in the future. 1 free-word reply was that only if the clients demanded it. 1 also selected “More benefits from the 3D model”. Better and cheaper software were selected by no participants. This is to contrast with the results from Latvia, where the price of software was considered too expensive.

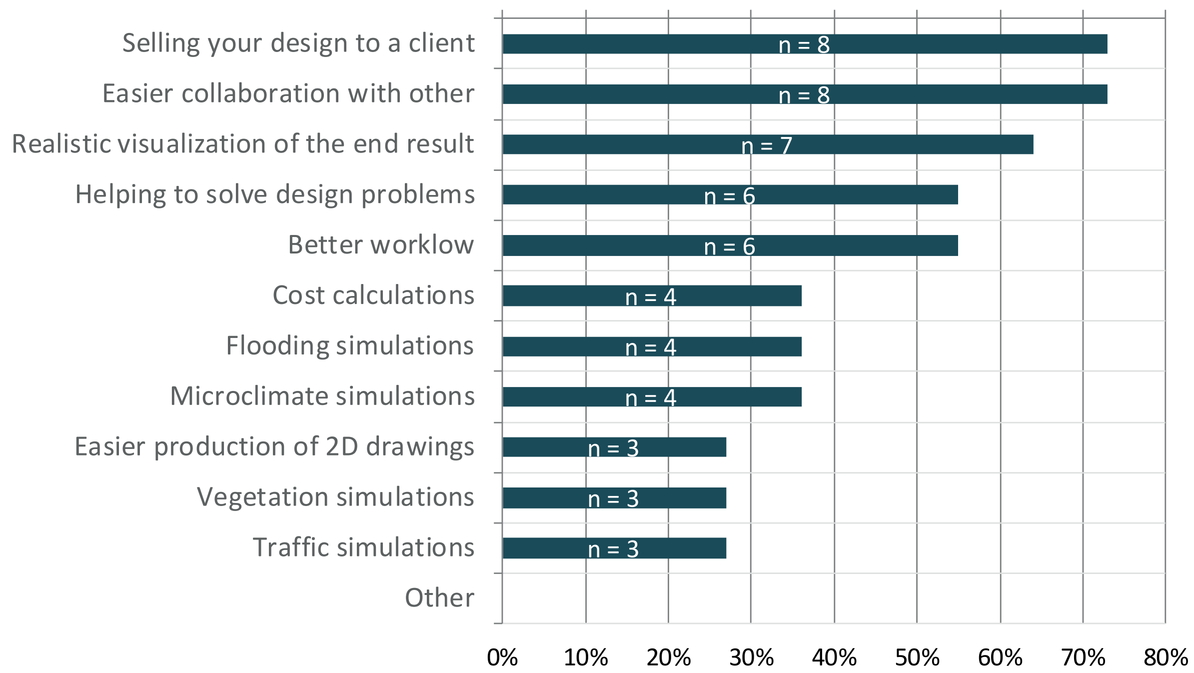
What do you think would be required for you to use 3D models in the future?
Number of respondents: 10, selected answers: 19



The main benefits that those who do not do 3D modeling would like to gain from 3D models were (out of 9 respondents):



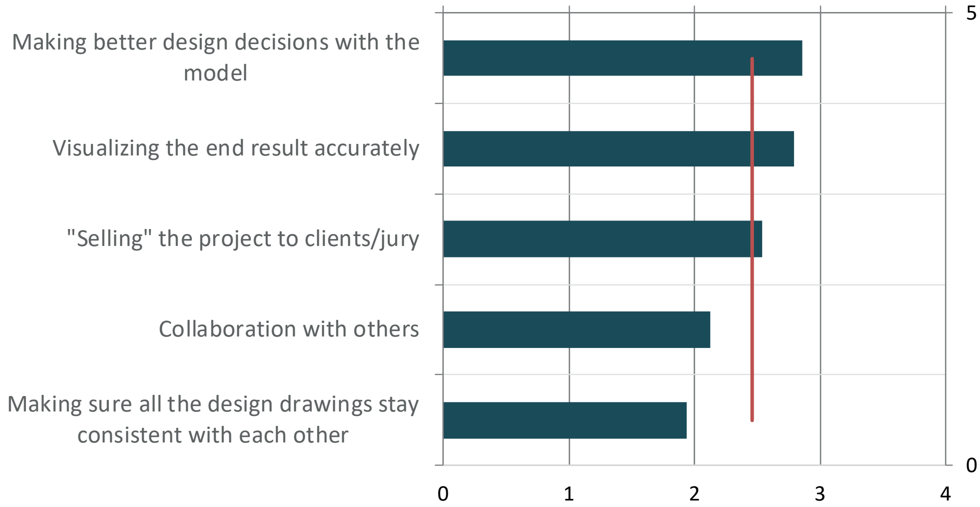
The main benefits that were expected were (out of 11 respondents):



The main discrepancies between results that were expected and results that would be preferred were that easier collaboration and easier cost calculations were expected more than they were preferred, and vegetation simulations were found slightly more desirable than they were actually expected. Otherwise the levels of expectations and desires were closely related. From this it can be concluded that those who do not do 3D modeling expect that their desires would be largely met if they did start using 3D models as part of their workflow.

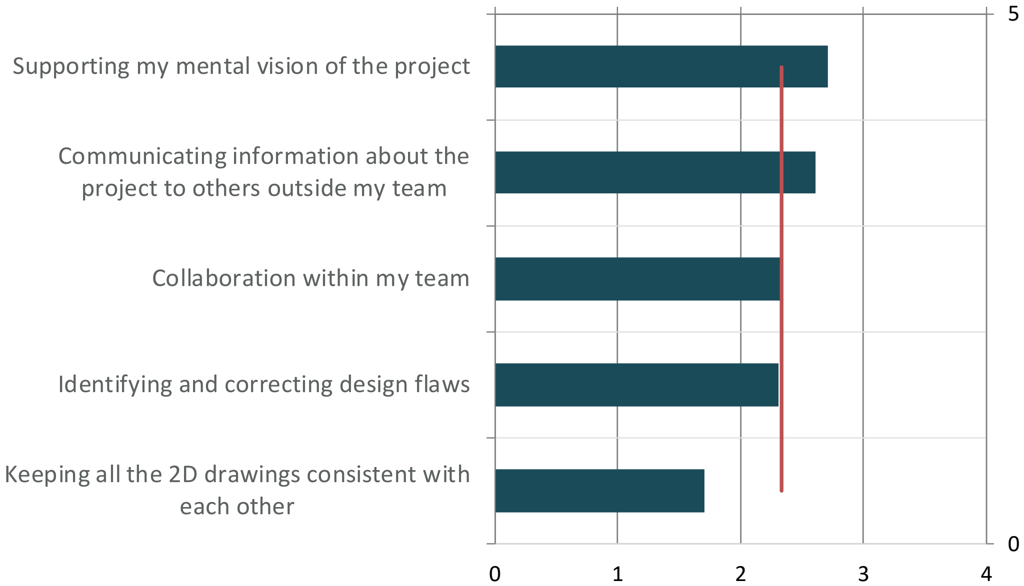
4.2.3. The benefits of 3D modeling

The expected benefits by the “no 3D modelling group” had similarities to the reasons why people who used 3D models chose to use them as part of the workflow. The most important reasons were considered to be (from 49 respondents):



Score of 0 being unimportant, 4 being very important

The actual benefits of 3D modeling were rated as such in the following parts of the design process (with 62 participants):



0=unnecessary, 1=not very beneficial, 2=somewhat beneficial, 3=beneficial, 4=necessary

Similar to what the non-3D-modelling group expected, easier collaboration was one of the larger benefits actually gained, although it was not the most desired feature. The most desired feature was, instead, making better design decisions, with visualising the end results coming in second. The largest benefit gained is related to both: Supporting the mental vision of the designer. However, identifying design flaws was only the 4th biggest benefit gained. This shows that there is some discrepancy between what is desired and what is gained - the 3D model is expected to have slightly more benefits for the design than is reportedly gained. Instead of improving the design, the largest benefit was found to be visualization - for both the designer themselves and for others. Helping with 2D drawings was found to be least important and least beneficial.

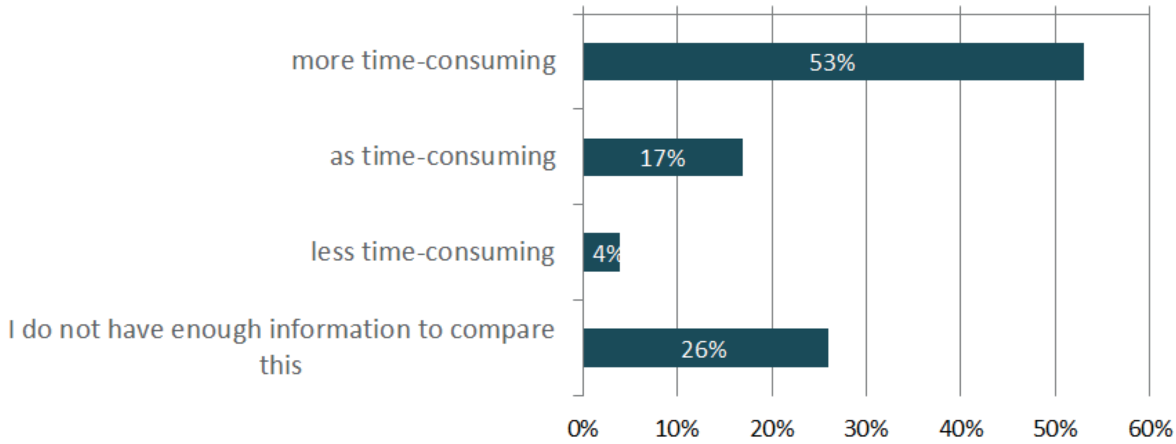
In the free word section, 5 mentioned client demands as other important reasons to do 3D modeling. Several comments related to visualization; some things being more easily understood in 3D, 3D being easier to understand for others and for creating perspective drawings. Being able to understand the experience of space was also mentioned. Some more technical aspects such as having to do volume calculations and creating machine control models were also mentioned. In the benefits gained section, there was a comment relating to the 2D drawings getting a low score, saying that it would be preferrable to be able to produce 2D drawings from the 3D model, instead of the other way around, as it often is currently. If the drawings could be produced directly from the 3D model, it would be more beneficial.

Interestingly, no one mentioned cost calculations, flooding simulations, microclimate simulations or vegetation simulations as benefits gained in the free word section, although those were expected or desired by the non 3D-modelling group. This indicates that those who do not have experience with 3D models may have higher expectations than the software are currently capable of. However, the three most important benefits of 3D models were considered to be the same by both 3D modelers and non 3D modelers:
- realistic visualization of the end result
- helping to solve design problems
- selling your design to a client

4.2.4. The problems with 3D modeling

Please compare how much time was spent on similar projects with the most and least 3D modeling. Would you say the project with more 3D modeling in comparison to the one with less 3D modeling was:

Number of respondents: 47



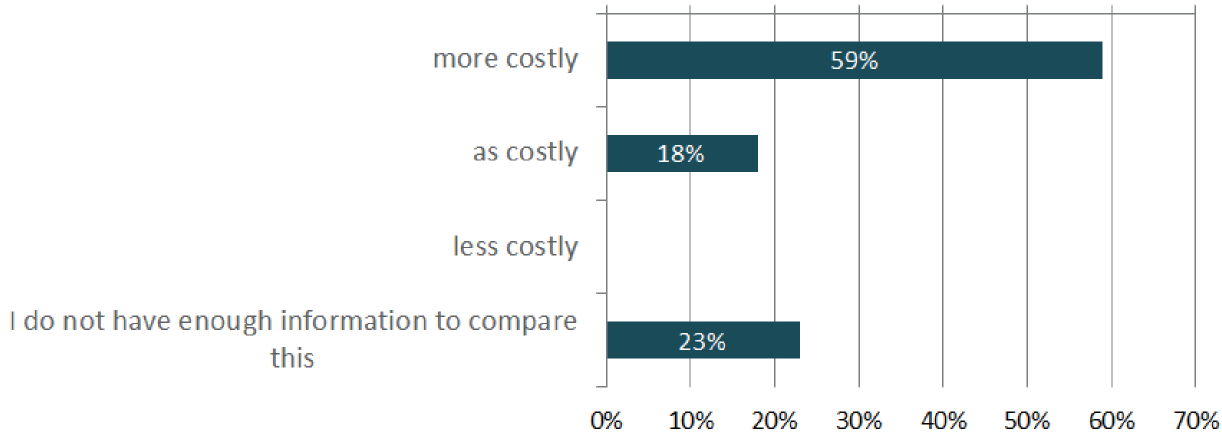
In a question with 47 respondents, a project with more 3D modeling was found more time-consuming by 53%, as time-consuming by 17% and less time-consuming by 4%. 26% stated they did not know. In the freeform answers, the following were stated as reasons (among others):
1. Less: 4 said that 3D modeling can be faster, because you can get many 2D drawings out of the software. 1 said that it might save time if it is used as part of the design process.
2. More: 6 mention the difficulty of learning the software. 3 of these mention problems with the software itself
3. More: 3 mention that 3D modeling is an extra work stage in the design process

In the freeform answers it was mentioned that producing 2D drawings takes extra work, and that 2D drawings alone are sufficient and faster to make than 3D models. This is interesting because, of those that answered that 3D models can make the design process less time-consuming, the ability to produce multiple 2D drawings from the 3D model was the biggest factor. Software differ in their ability to produce 2D drawings, so it is possible for people to have gotten contradictory results. However, it is notable that when 2D drawing production was efficient, it was perceived to make using 3D models more efficient as part of the design workflow.

Thus if efficiency of 3D modeling is to be improved, 2D drawing production should be improved. Another way to improve efficiency is to either raise the skills in the software or to choose a software that is easier to learn and use, as those were also some of the biggest caveats. Some also mentioned the complexity of the project or the model - for this reason it should be discussed with the client what is necessary to represent in the 3D model.

In a question of the costs of 3D modeling with 17 respondents, 59% thought projects with more 3D modeling were more costly, 18% less costly and 23% did not know. There were few replies to the actual costs of the software.

Please compare the costs of similar projects with the most and least 3D modeling. Would you say the project with more 3D modeling in comparison to the one with less 3D modeling was:
Number of respondents: 17



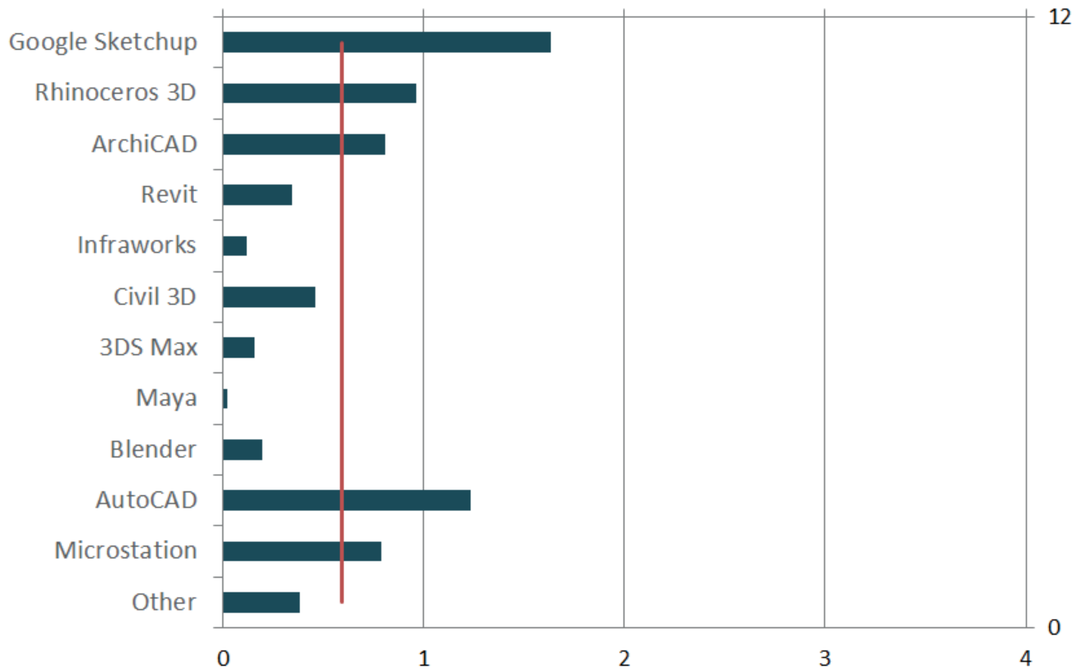
Because 3D modeling is almost always perceived to be more costly and time-consuming, it can be concluded that the benefits of 3D modeling should be perceived to override the costs in order for Finnish landscape architects to make use of it in their projects. Usually this includes a request from the client to make a 3D model.

4.2.5. 3D modeling software

Overall, the most popular 3D modeling software were found to be Google Sketchup, Rhino and ArchiCAD (excluding AutoCAD and Microstation, which are more often used for 2D drawing). During studies Sketchup and Rhinoceros were by far most commonly used, correlating with the fact that they were taught to landscape architects at Aalto university. The most popular ones used at work were Sketchup, AutoCAD, Microstation, Rhino and ArchiCAD. Teams were often reported to use Sketchup, Civil 3D, 3DS Max, Infraworks and AutoCAD.

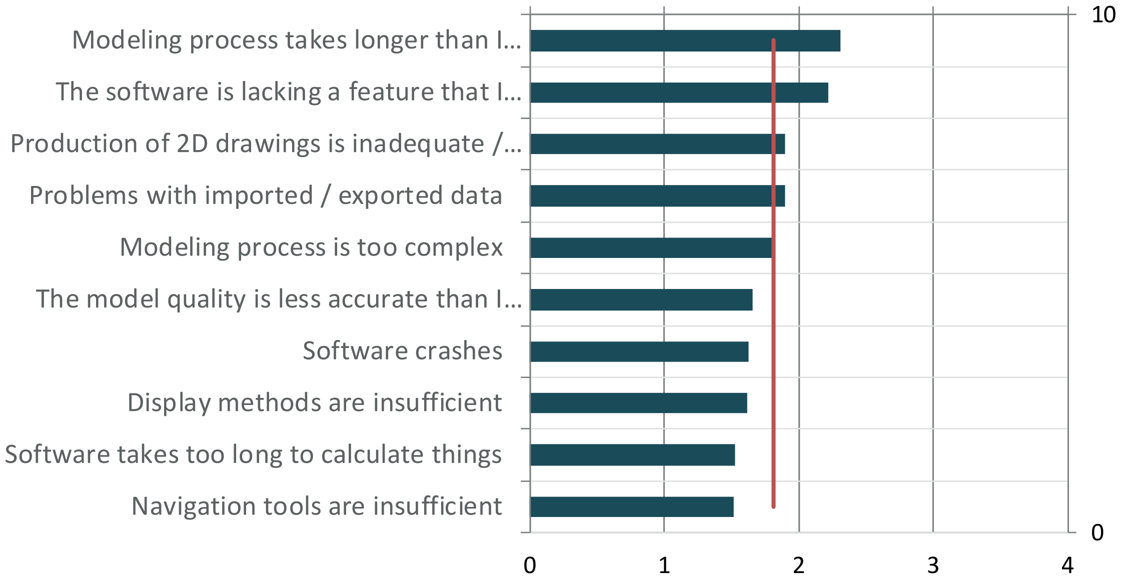
Software used in	**studies**	**at work**	**by team**	**Total**
Google Sketchup	25	14	7	**46**
Rhinoceros 3D	19	8	4	**31**
AutoCAD	7	10	6	**23**
ArchiCAD	9	7	5	**21**
Microstation	5	8	3	**16**
Revit	3	3	4	**10**
Civil 3D	2	6	7	**15**
Other	5	4	1	**10**
3DS Max	2	1	6	**9**
Infraworks		2	6	**8**
Blender	1	2	1	**4**
Maya				
Number of respondents	**38**	**30**	**15**	**83**

How would you rate your familiarity with these software in 3D modeling?
Number of respondents: 52, 0=Never used, 4=Expert



Overall, respondents encountered all listed software problems some of the time. Lengthy modeling process and lack of features were encountered more often than other problems. The least problems were had with navigation tools, display methods and software calculation speed.

To which extent have the following been a problem with the software you are the most familiar with? (From Never to Always)
Number of respondents: 51



Sketchup had 12 respondents that were able to evaluate the software deficits, Rhino had 11, ArchiCAD 8. The others had too few users to be analyzed more closely.

If you had to pick one software that you are most familiar with, which one would it be?

Software	Total	Students	Employees	Project leader and supervisor
Google Sketchup	**12**	7	4	4
Rhinoceros 3D	**11**	9	2	1
ArchiCAD	**8**	5	3	1
Revit	**2**		2	
Infraworks				
Civil 3D	**3**		3	1
3DS Max				
Maya	**1**		1	
Blender	**2**	1	2	
AutoCAD	**4**	1	2	2
Microstation	**7**	1	5	2
Other	**2**	1	1	1
Number of respondents	**52**	**25**	**25**	**12**

According to the survey, a benefit of Sketchup was the simplicity of modeling process, whereas modeling accuracy and 2D drawing production suffered. Rhino was found to have good features, but the production of 2D drawings was inefficient. ArchiCAD was found to be good at producing 2D drawings, but lacking in features. Results of the software comparison in the survey were found to be mostly inconclusive.

4.3. Reflections

According to the survey Finnish landscape architects consider 3D modeling to be beneficial, but not having the skills to use the software can be an obstacle to using 3D models, along with not having time to do 3D modeling. Those who do not have experience with 3D modeling expect that their desires would be largely met if they did start using 3D models as part of their workflow. However, they may have higher expectations than the software are currently capable of. The three most important benefits of 3D modeling were considered to be the same by both 3D modelers and non-3D-modelers alike, however:

- realistic visualization of the end result
- selling your design to a client
- helping to solve design problems

3D modeling is almost always perceived to be costly and time-consuming by Finnish landscape architects, so the benefits should override the costs for it to be considered as part of the design process. Team leaders consider this to mean that the client should request for a 3D model rather than suggesting to use it as part of the process themselves, to ensure the client will cover the cost of 3D modeling. When the request comes from the client rather than from the team, making a 3D model can be considered as an extra step rather than an integral part of the design process.

To improve cost-benefit, the time-consumption of 3D modeling in the design process could potentially be reduced by improving 2D drawing production, as it was found to have the biggest time-reducing effect. Another way to improve efficiency would be to either raise the skills in the software or to choose a software that is easier or better suited for the task. Different 3D modeling software were found to have different benefits and deficits, eg. some may be more efficient at creating 2D drawings than others. Another thing that could improve efficiency would be if 3D modeling was included as a more integral part of the design process, rather than an added step at the end. However, this may require reconsidering the workflow overall - and the improvement of the software before it is fully feasible - as well as a change in attitudes towards the necessity of 3D modeling.

Because 3D modeling is not considered to be a necessary part of the design process, it is not always used. Of the parts of the design process that were listed, many were considered to benefit from 3D modeling, however, rarely 3D modeling was considered necessary in order to complete those tasks. Of those landscape architects that had done 3D modeling, only 55% had spent at least 20% of their time on 3D modeling at least sometimes in a landscape architecture design. Having no experience with 3D models was rare (15%), but having little experience was common. Those that had used a certain 3D modeling software usually had little experience with it, considering themselves beginners or average users. Ways to utilize 3D models were limited: Visualization of the design was one of the most important reasons 3D modeling was done, but 3D models were more often used as a basis for hand-drawn or photoshopped sketches rather than actual renderings.

The most commonly used 3D modeling software was Sketchup, which is used for light-weight 3D modeling. This fits with the other results of the survey - 3D modeling is not done in-depth. Most Finnish landscape architects have barely scratched the surface of what 3D modeling can do for landscape architecture. At the same time, the expectations for 3D modeling may be both too high (by those with no experience with 3D models) and too low (by those who make the decisions), as the current possibilities and limitations of 3D modeling for landscape architecture are not truly known. Either way, the results are rather modest, and 3D modeling remains to be fully integrated and appreciated as a vital part of the design process. The benefits are seen and appreciated but are not fully taken advantage of due to the perception that the benefit may not justify the cost, both in time and money.

5. Software comparison

5.1. Methodology

The goal of the software comparison is to evaluate the performance of different 3D modeling software on common landscape architecture design tasks. Software that are included in the software comparison are selected by considering the targeted profession, the most commonly used 3D modeling software in Finland according to the survey, as well as the professional 3D modeling experience of the author. Design tasks used to test the software are selected by considering which ones best allow testing central features for 3D modeling landscape architecture. These central features are determined by considering four examples of a landscape architecture 3D modeling task. The software are evaluated on a scale from 0-5 on each subtask based on the ability to complete each step as well as the efficiency in completing the subtask.

5.1.1. Software selection

Software typologies are created for choosing which software to include in the practical comparison. The typologies are based on the profession the 3D modeling software is marketed towards as well as the type of 3D modeling the software is capable of. The results of the survey on most popular 3D modeling software are compared against these typologies. The goal is to include software that are likely to be useful in landscape architecture but have fundamental differences in the way they function, so that there will be enough variety in the results of the comparison. Altogether these findings are used to choose which software to include in the comparison. The professional 3D modeling experience of the author is considered as well.

Software categorization according to marketed purposes

	Universal 3D modeling	Video games / animation	Product design	Infrastructure, civil engineering & civil planning	Architecture	Landscape Architecture (total number of users in survey out of 83 respondents)
Google Sketchup	X					**46**
Blender	X	X				4
Z-Brush	X	X				
Mudbox	X	X				
Maya	X	X				
3DS Max	X	X	X			9
MODO	X		X			
Rhinoceros 3D			X			**31**
Infraworks				X		8
Civil 3D				X		15
ArchiCAD					X	**21**
Revit					X	10
AutoCAD (mainly 2D, but includes 3D)			X	X	X	23
Microstation (mainly 2D, but includes 3D)				X	X	16

Figure 4. Software categorization according to marketed purposes.

Selected software

Taking into account the amount of software users in the survey as well as a variety of software typologies, combined with the 3D modeling experience of the author, these are the software chosen for the comparison. ArchiCAD had more users than Revit in the survey, but due to more recent modeling experience and the similarity with Revit, Revit was chosen instead.

Software	Users in survey	Targeted profession	3D modeling experience of author
Google Sketchup	**46**	Universal 3D modeling	Studies (1 year ago)
Rhinoceros 3D	**31**	Product design	Studies (1 year ago), Teaching (4 years ago)
Civil 3D	**15**	Infrastructure, civil engineering & civil planning	Work (current)
Revit	**10**	Architecture	Work (3 years ago)
Infraworks	**8**	Infrastructure, civil engineering & civil planning	Work (current)

Figure 5. Software selection.

5.1.2. Examples of 3D modeling design tasks

The 3D modeling design tasks are chosen out of three tasks done by the author at consulting office FCG Suunnittelu ja tekniikka Oy. The original designs were done by author using AutoCAD Map 3D and were modeled using Civil 3D. This part of the design work was paid for by the client. All 3D models done with other software are done as unpaid independent work of the author, only the original design and Civil 3D model are paid for. The Skanssi[1] project was commissioned by the city of Turku, and the master plan was designed by Sweco before FCG being commissioned to design the construction plans.

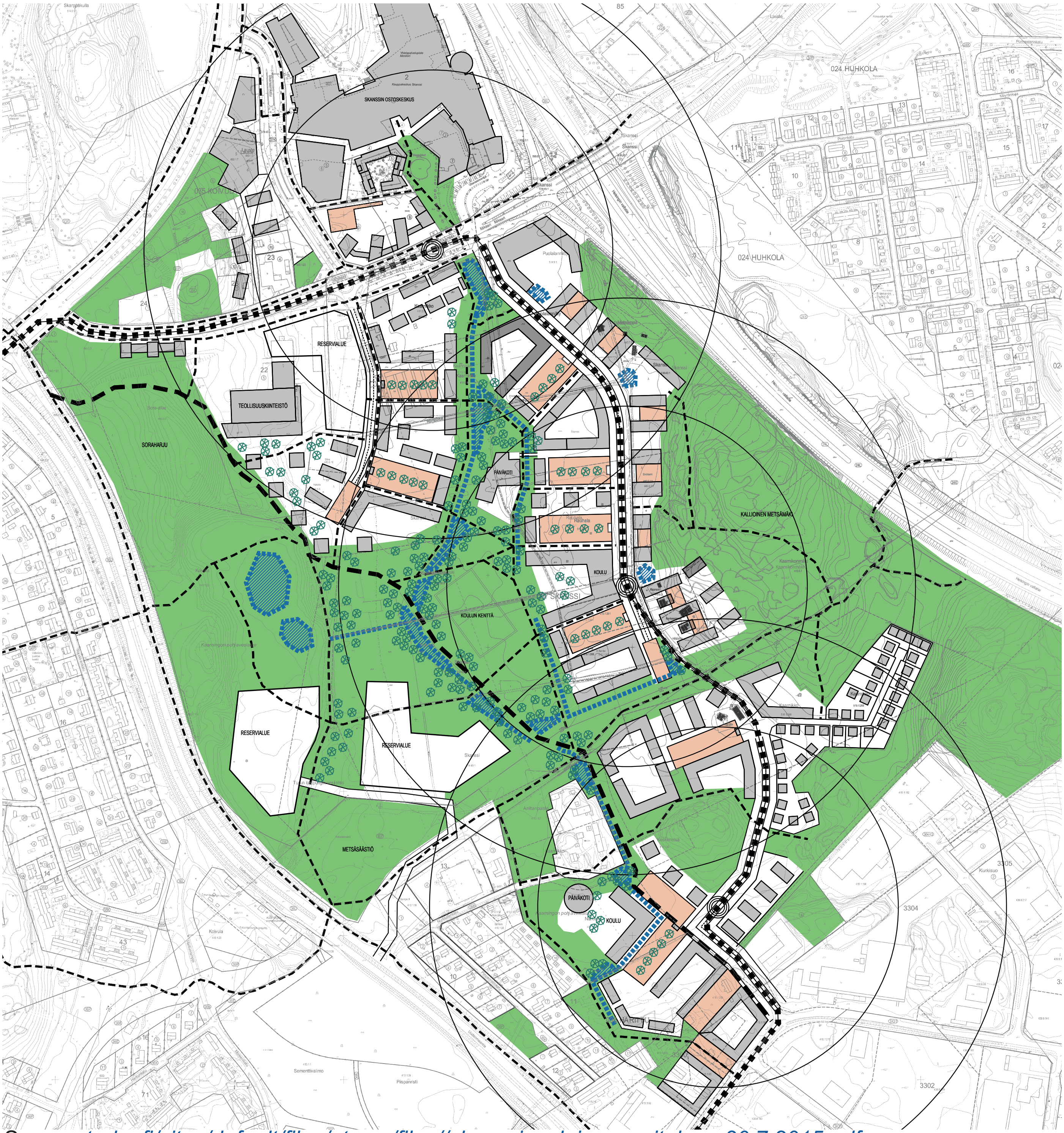
The final 2D drawings produced of the designs are construction drawings. No presentation drawings have been requested by the client, so drawings and 3D models are produced on a technical level rather than for aesthetic purposes. The drawings presented in this thesis are not of the finished designs, rather depicting designs that are a work-in-progress.

Using real design projects rather than a hypothetical scenario allows testing the performance of the 3D modeling software in a real work-life landscape architecture design workflow. The three designs that are considered were chosen because of author's independent design work done in them. The author had also participated in the idea competition of the Skanssi park as a student, so she had prior knowledge of the area before participating in the construction design phase of the park. However, the design tasks are considered mainly in terms of allowing the evaluation of software performance in common landscape architecture design tasks, rather than the evaluation of design principles.

In the next chapters the steps required to do the 3D model related to the task are listed. These steps are compared against each other and are used to formulate subtasks that can be used to evaluate the software. Afterwards the design tasks that are used to evaluate the software are chosen.

1 Skanssi is a planned city quarter of Turku that includes new housing, services and a central park. The planning of the central park began with an idea competition for students and was continued by Sweco, consulted by landscape architecture office VSU, with FCG being responsible for the final construction phase.

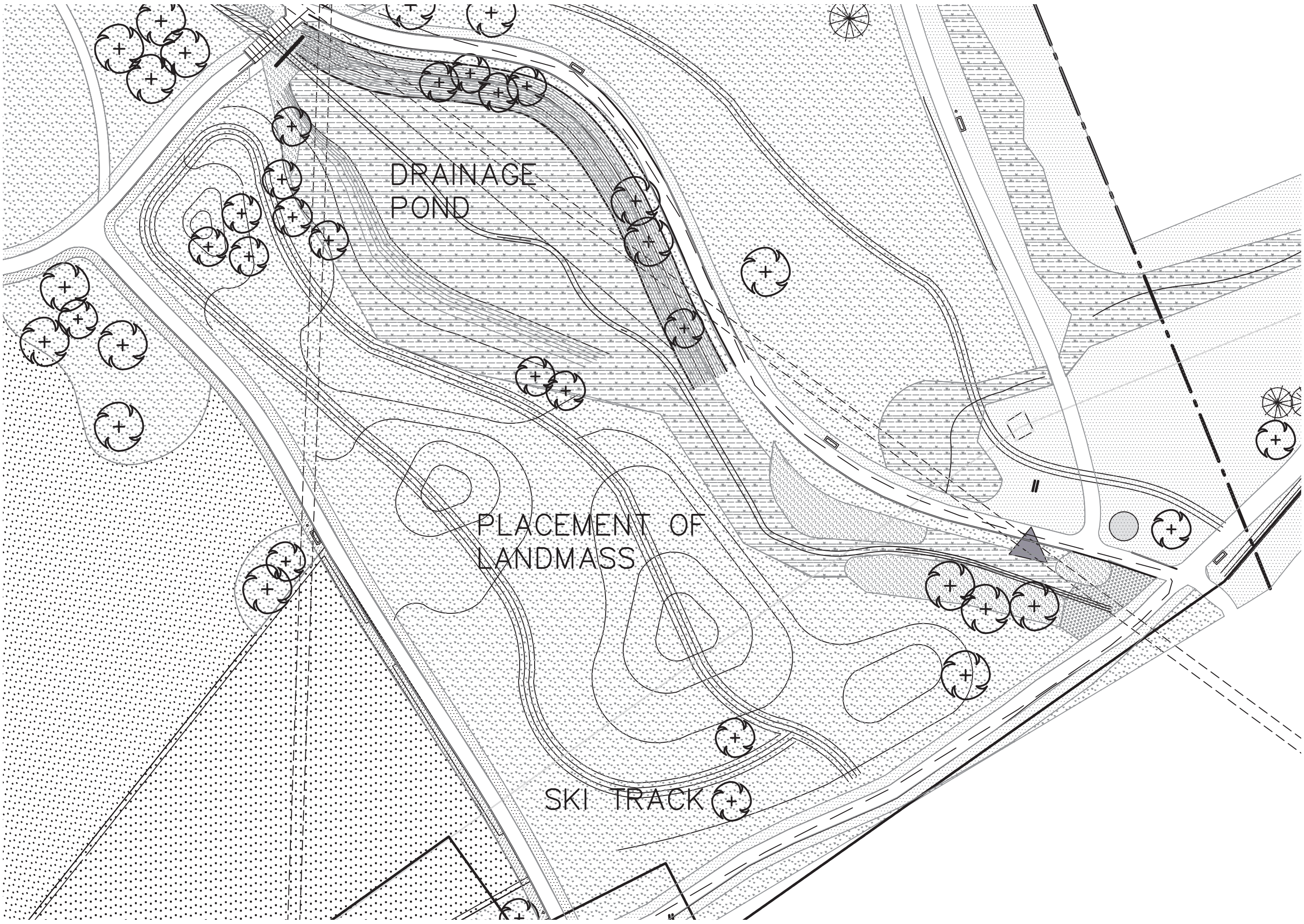
Skanssi - City plan



Source: turku.fi/sites/default/files/atoms/files//skanssin_yleissuunnitelma_30.7.2015.pdf

The Skanssi park plan is surrounded by planned housing blocks, a shopping centre, a school and a kindergarten. Central to the park plan is a stormwater drainage basin. Currently there is a shallow ditch in the area, but the water will be redirected and the drainage area expanded due to the planned housing. The excavated ground material is planned to be placed within the park in order to support cost-efficiency. Therefore the volume of landmass excavated and placed must be calculated. The following design task is part of the ground material replacement.

Skanssi - Ground massing

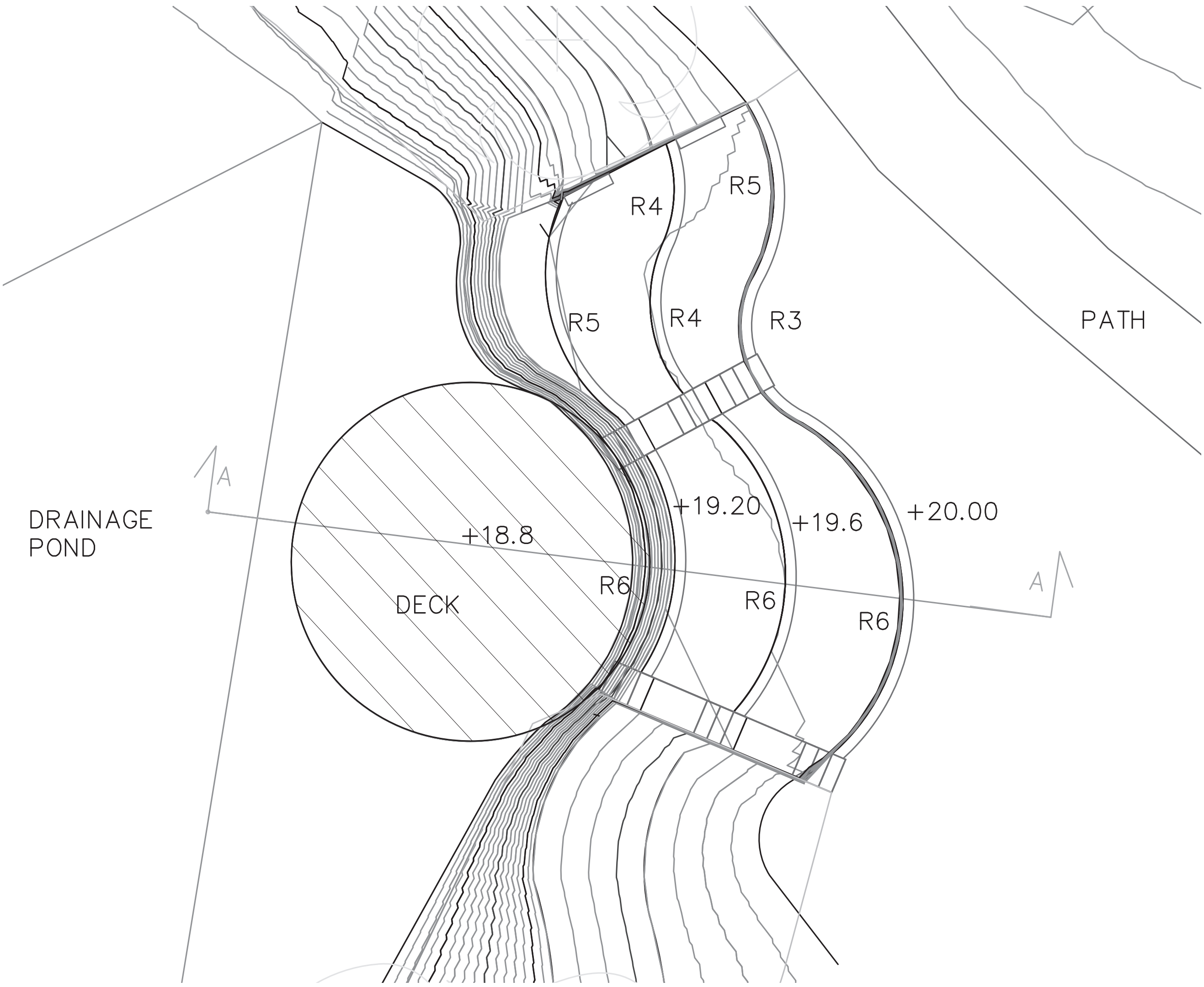


The area shown above was determined to be suitable for placing the excavated landmass. It was determined by a geodesigner that the maximum massing above current ground level is +1,5m because of the clay soil, which might cause heavier masses to become unstable. A ski track is included in the master plan. The role of the author in the design was to determine the shape and volume of the massing placed in this area. The author decided to take into account the skiing experience as well as the maximum height in the design. At the time of this design phase, the total excavated ground mass was unknown, so additional ground massing was placed elsewhere later on in the design process. A 3D model of the design was created in order to calculate the volume of landmass placed and to determine further placement needs.

Steps of the design process:

1. The software should have **geographic coordinate systems**, as this is a real-world design project. Placing the drawings and the 3D model in a coordinate system allows for easier collaboration with other designers that use the same coordinate system.
2. T**he existing terrain needs to be imported into the 3D model**, so that the design can be related to the current landforms and the volume of added landmass can be calculated.
3. After this **the new landforms can be designed** taking into account the design goals. This has been done using 2D contours.
4. **The mesh / surface is created from 2D contours.**
5. Now **the designed landform can be viewed in 3D** and how well the design goals have been fulfilled can be evaluated.
6. The **the designed surface should be connected to the surrounding terrain model** to make sure there are no gaps or inconsistencies (unexpected hills or valleys along the connection).
7. Then **the volume of added land mass can be calculated**. This information will be used during construction.
8. **Contours from the 3D model are created,** which can be shown in plan view.
9. For the purposes of this study, **compatibility with other software** could be studied.

Skanssi - Amphitheatre



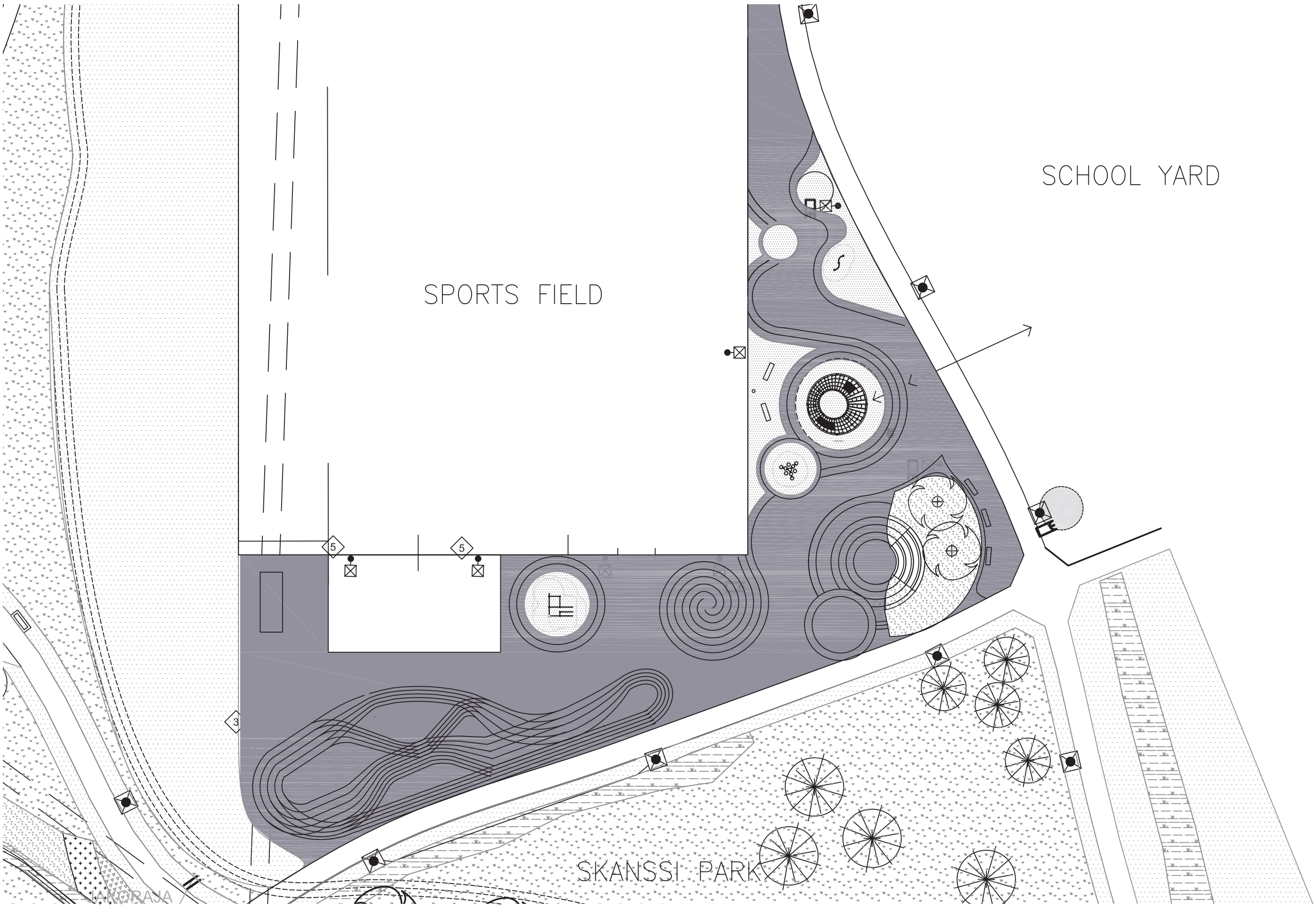
In the master plan made by Sweco and VSU it was determined that an amphitheatre would be placed on the shore of the drainage pond. A dock would serve as the performance stage and a seating area would be made from old curbstones. There are suitable old curbstones available with the radius of 3, 4 and 5 meters, so the design was created by author using these as the parameters. Other restrictions were that the dock has to be on the level of high water, and the highest seating on the level of the nearest path. The height of the nearby path was later changed, so the amphitheater was adjusted accordingly. These pictures are showing the state of the amphitheater design prior to changes made to the path level. A 3D model was created to visualise the height differences.

Steps of the design process:

The steps that are not repetition from previous tasks are marked in blue.

1. Uses the same coordinate system and the same existing terrain as the other Skanssi projects.
2. Designing the amphitheater within design restrictions.
3. Creating a 3D model of the amphitheater.
4. Viewing the designed structures in 3D to check quality of design.
5. Calculating the amount of stone materials used.
6. Creating plan view.
7. Creating structural section.
8. Adjust the top height of amphitheater to match changed path level.

Skanssi - Sports park



The city of Turku has determined in the city plan that there will be a sports park located next to the planned school. The sports and play equipment should be suitable for high school students. In the master plan it was determined that there would be a small amphitheater for outdoor teaching.

FCG was commissioned to design the sports park in more detail. The city of Turku requested for the inclusion of "speed stripes", circles, spirals, etc. as part of the design language to create an illusion of movement. The author designed the park on these prerequisites. A 3D model of the park was created for the "combination information model" of the park project. For the combination information model it was requested to represent the geometry of the surface level of the terrain, as well as locations of furniture and vegetation. Lighting from lighting designers and paths from streets designers are incorporated.

Steps of the design process:

The steps that are not repetition from previous tasks are marked in blue.

1. Uses the same coordinate system and the same existing terrain as the other Skanssi projects.
2. Designing the sports park in 2D using the circles and speed stripes as the form language.
3. Locations of sports equipment are selected.
4. The surface materials used in the design are selected and necessary detail sections created.
5. Sports equipment and street furniture are chosen.
6. Vegetation are chosen by a horticulturist.
7. Lighting plan from lighting designers is incorporated.
8. Paths from street designers are incorporated.
9. The amphitheater is designed and structural section is created.
10. In the 3D model, the following are represented
    - geometry of the surface level of the designed landforms
    - amphitheater
    - locations of furniture
    - locations of vegetation
    - incorporated lighting design
    - incorporated paths
11. Connecting the designed 3D surface to the surrounding terrain.
12. Creating contours from the 3D model.
13. Create plan view.
14. Create sections.

5.1.3. Identified 3D modeling subtasks

From the steps taken in the example tasks, these 3D modeling subtasks can be identified.

1. Setting up the 3D model
- Does the software have a coordinate system library?
- Can the site plan be imported?
- Can the existing terrain model from Maanmittauslaitos be used?

2. Modeling landforms
- 3D modeling from contours
- Connecting the designed landforms to the surrounding terrain
- Calculating the volume of the designed landform
- Usability of resulting contours from surface

3. Representation of other elements of the landscape design
- Vegetation
- Equipment (Street furniture / sports equipment)
- Structures (Amphitheater, etc.)
- Routes
- Lighting
- Water

4. 2D drawings
- site plan
- section

5. Viewing the 3D model
- perspective view

6. Compatibility and file formats

5.1.3. Design task selection

	Skanssi - Ground massing	Skanssi - Amphitheatre	**Skanssi - Sports park**
1. Coordinate system library	**X**	X	**X**
1. Importing the site plan	**X**	X	**X**
1. Importing the existing terrain model from MML	**X**		**X**
2. 3D modeling from contours	**X**		**X**
2. Connecting the designed landforms to te surrounding terrain	**X**		**X**
2. Calculating volume	**X**		
2. Resulting contours from surface	**X**		**X**
3. Routes		X	**X**
3. Structures		X	**X**
3. Playground equipment / street furniture			**X**
3. Vegetation	**X**		**X**
3. Lighting		X	**X**
3. Water	**X**	X	
4. Site plan	**X**	X	**X**
4. Section		X	**X**
5. Perspective view	**X**		
6. Compatibility and file formats	**X**	X	**X**

Figure 5. Design task selection.

Considering the comparison chart, it can be concluded that the Skanssi sports park includes most of the wanted elements. It is not necessary to include the separate Amphitheatre task, because the sports park already includes an amphitheater made from recycled stone material. The separate ground massing task may not be necessary either, as landforms are also included in the Skanssi sports park. However, it may be helpful to divide the evaluated tasks between the two design tasks.

5.1.4. Software evaluation

The selected design tasks are used to evaluate the performance of the 5 selected software in 3D modeling landscape architecture. The sub-tasks that are to be evaluated are divided into two separate 3D modeling tasks: the ground massing task and the sports park. Modeling each sub-task is attempted in practice with each 5 software and the results are shown side-by-side. Screenshots of the hands-on 3D modeling are provided as proof of the results. Software manuals are also referred to as needed.

After each sub-task has been tested, the results are scored from 0-5, with 5 being the highest score. 4-5 (good) is visually indicated by green, 2-3 (intermediate) by orange and 0-1 by red. A high score means the software is able to perform the task well relative to the other software in the comparison. An intermediate score means there are problems, but completing the task is not impossible. A score in the red range means the task cannot be done or only a small part of it can be done. The degree of task completion as well as efficiency are considered in the scoring.
It must be noted that a high score does not mean another software could not complete the task better in the future, rather it reflects good performance in relation to current expectations.

The subtask may include several positives and negatives in the evaluation, but the overall score is decided by which parts are most vital for the evaluation. If there is both a red comment and a green comment, but the total score is 1, then the negative comment was given more weight, with the positive one considered only a minor improvement, essentially giving a +1 to an otherwise nonfunctional property.

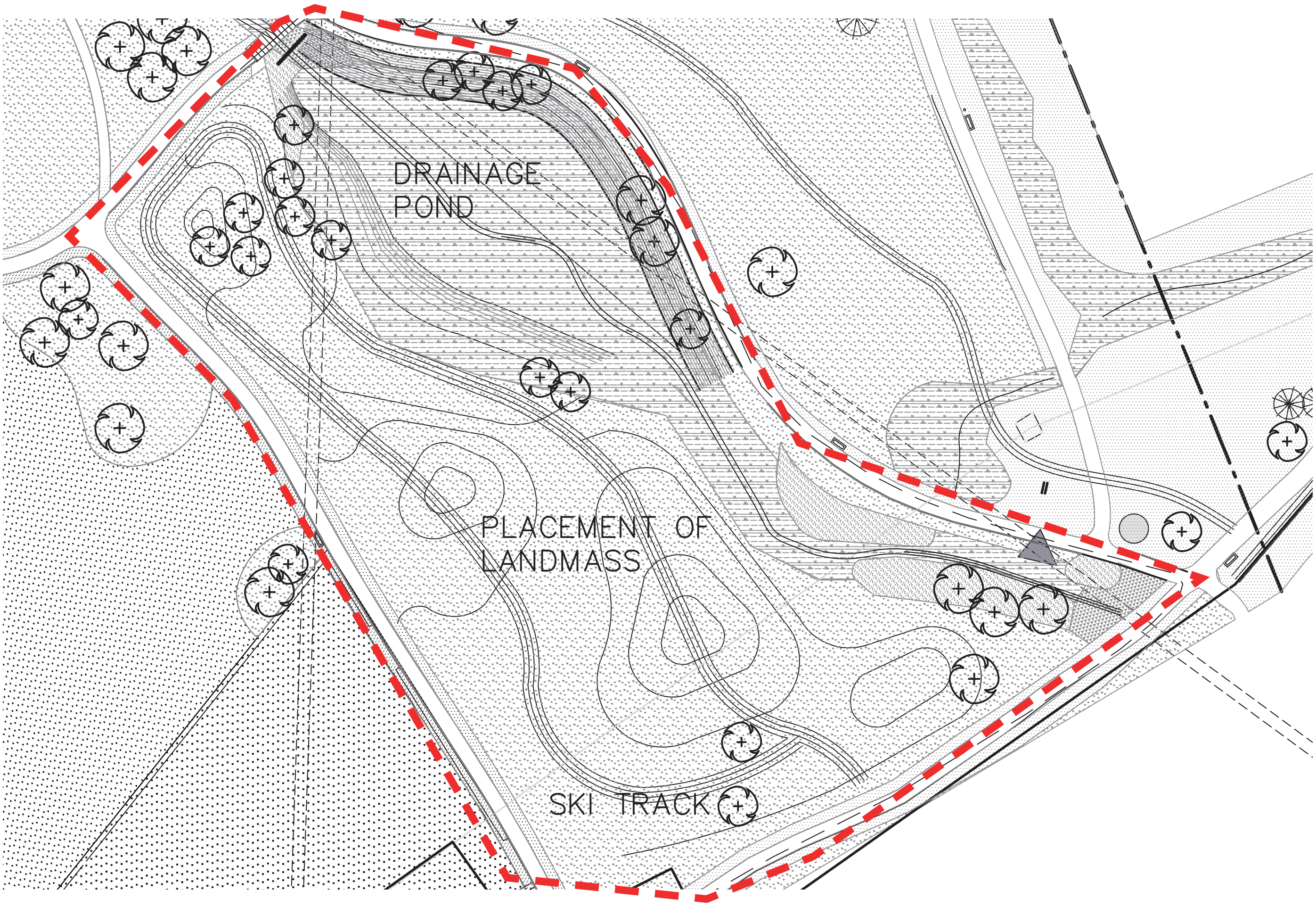
In the conclusions, the benefits and deficits are summarised and strategies to choose the most suitable software are considered. Strategies to improve 3D modeling software and the use of 3D modeling are also considered.

5.1.5. Limitations

A challenge of the software comparison is that only the current version of the software can be tested and future developments cannot be taken into account. However, considering the target audience of the software, it can be predicted which features are likely improve in the future and which are not. It is also more difficult to prove that something isn't possible than to prove that something is possible to do in a given software, but official information from the developers can be used to alleviate this fact.

5.2. Findings

5.2.1. Skanssi - Ground massing



This design task is used as an example of how landforms are 3D modeled due to the design task being centered around placement of new landmass. Before the volume of the placed landmass can be calculated, a 3D model of the existing terrain must be placed. In Finland laser scanned terrain models can be acquired from MML (Maanmittauslaitos). In order to use the terrain files from MML, the 3D modeling software should be able to open the provided file format (ASC or TIFF). The 3D modeling software should also have a geographic coordinate system to allow for accurate placement of the terrain model.

The site plan of the Skanssi park must also be placed in the 3D model, so that the new landmassing can be placed in relation to the design. Therefore the software should also be able to open the file format the site plan is in (DWG). The site plan should also be placed in coordinates.

The new landforms have been designed by author using contours, taking into account that the clay soil can only support max.+1,5m added landmass. A ski track and the experience of space was also taken into account in shaping the landforms. A 3D model is required in order to calculate the volume of landmass placed.

The landmass placed in this design task is excavated from the nearby drainage pond. In this project, the drainage pond is designed and 3D modeled by storm water management specialists. Therefore the 3D modeling tools that relate to water flow are given a more cursory look.

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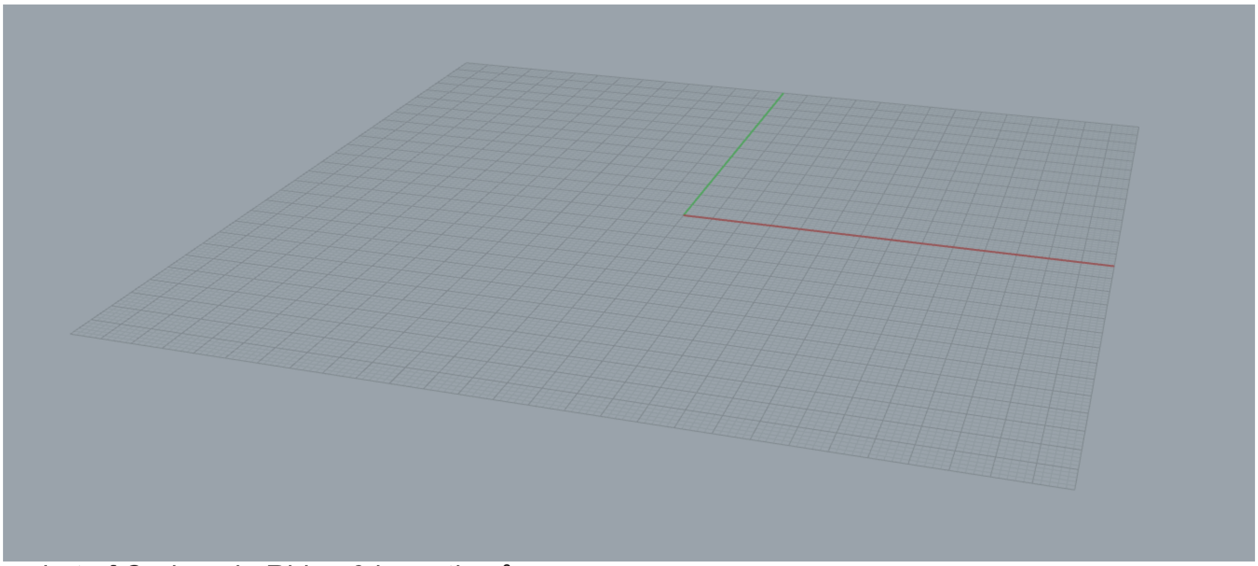
1. Setting up the 3D model
    - 1.1. Geographic coordinate systems / geolocation
    - 1.2. Importing the site plan
    - 1.3. Importing the existing terrain model from Maanmittauslaitos
2. Landforms
    - 2.1. 3D modeling from contours
    - 2.2. Connecting the designed surface to surrounding terrain
    - 2.3. Calculating volume
    - 2.4. Resulting contours from surface
3. Other elements of landscape design
    - 3.1. Water simulations

1.1. Geographic coordinate systems / Geolocation

Every 3D modeling software uses at least a user coordinate system (UCS) that is local to the 3D model. For example, in AutoCAD the UCS defines the horizontal and vertical direction of the “grid”, which is used eg. for setting the default direction of text.[1] Below is pictured the C-plane (grid) that defines the UCS in Rhino 6. The green line depicts the Y-axis and the red line depicts the X-axis. The Z-axis is the height. Note that in some software the role of the Y and Z axis may be reversed. The center point is called the 0-point, the origin.



Screenshot of C-plane in Rhino 6 by author.[2]

However, some software also include a geographic coordinate system (GCS) that places the model on the map. According to the explanation on the website of ArcGIS, GCS is “a method for describing the position of a geographic location on the earth’s surface using spherical measures of latitude and longitude”.[3] Some software are capable of translating the geographic location into values used by the UCS, the latitude usually corresponding with the Y-axis, and the longitude with the X-axis.

Different countries use their own coordinate systems. The coordinate systems that are most often used in Finnish landscape architecture projects are ETRS89.TM-35/Fin and ETRS89.FinlandGK-19-31. Some maps may, however, be in the old KKJ coordinate system. [4] All maps provided by the Maanmittauslaitos downloading service are in ETRS89.TM-35/Fin.

When setting up the model, the terrain models from Maanmittauslaitos will be used. This is why it is important to know if the software can use the ETRS89.TM-35/Fin coordinates. It is not impossible to make use of the terrain model without a GCS, but correctly positioning it in relation to the plan will be more difficult.

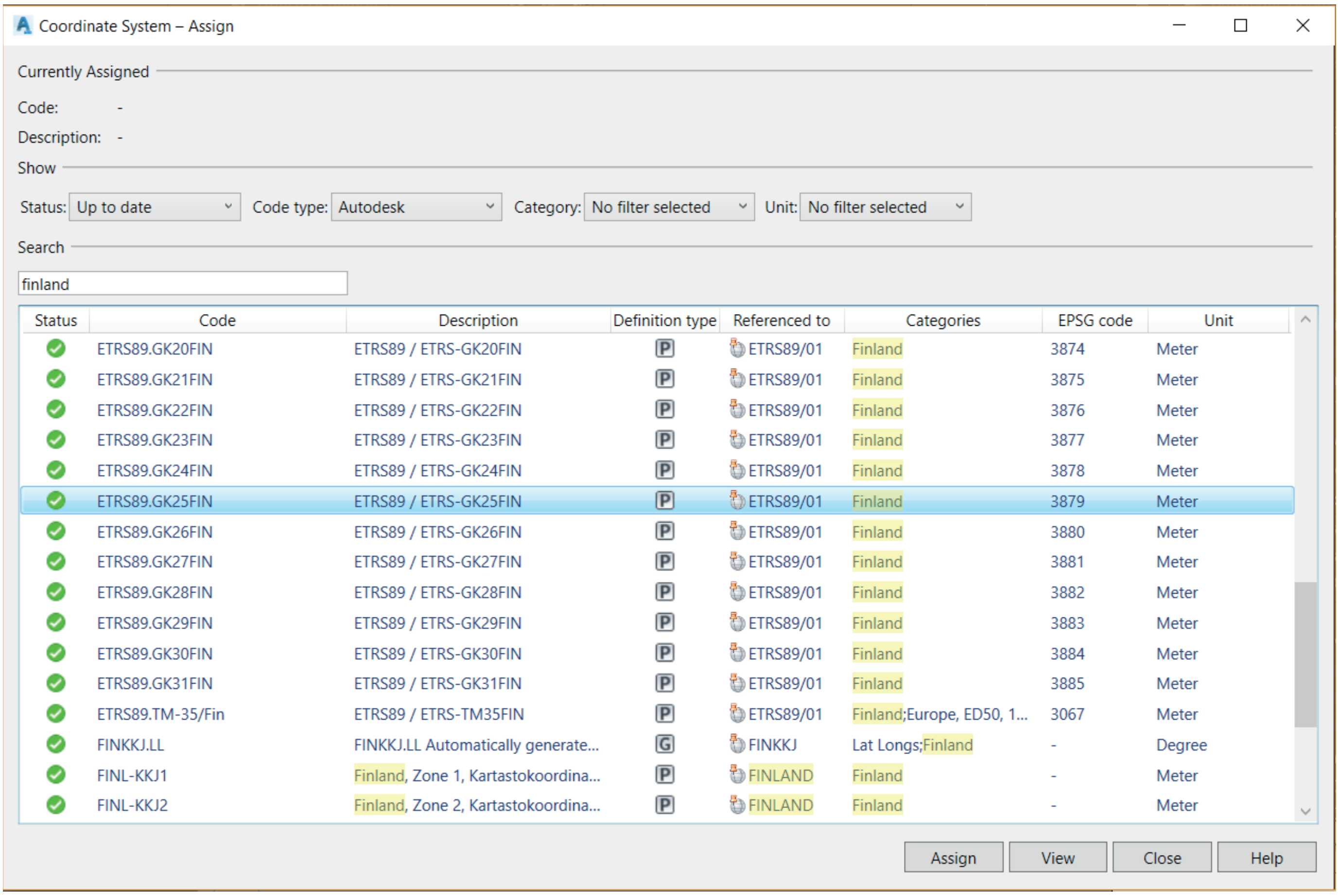
Note that synonyms of UCS and GCS can be used in some software manuals. This applies to other tools and tasks as well - different software can use different terminology for the same feature. Some synonyms for coordinate systems are listed in Revit’s software manual: http://help.autodesk.com/view/RVT/2019/ENU/?guid=GUID-E67ED082-2556-475B-84A7-4605329F612F

In the following pages, the software are evaluated according to whether or not they include a coordinate system library that allows using the Finnish coordinate systems. If a coordinate system library is not found, other forms of geolocation are looked at. It can be assumed that all software have a user coordinate system, so this is not evaluated.

1 Knowledge.autodesk.com. (no date). About the User Coordinate System (UCS) https://knowledge.autodesk.com/support/autocad-lt/learn-explore/caas/CloudHelp/cloudhelp/2019/ENU/AutoCAD-LT/files/GUID-C16311B2-789B-4A9A-8F73-BE27C901ED05-htm.html Accessed 28.7.2019
2 All screenshots in the software comparison are by author unless stated otherwise.
3 Desktop.arcgis.com. (no date). What are geographic coordinate systems? http://desktop.arcgis.com/en/arcmap/10.3/guide-books/map-projections/about-geographic-coordinate-systems.htm Accessed 28.7.2019.
4 Uikkanen, Eino. (no date). Suomalaiset koordinaatistot. http://www.kolumbus.fi/eino.uikkanen/geodocs/kkjgps.htm Accessed 28.7.2019.

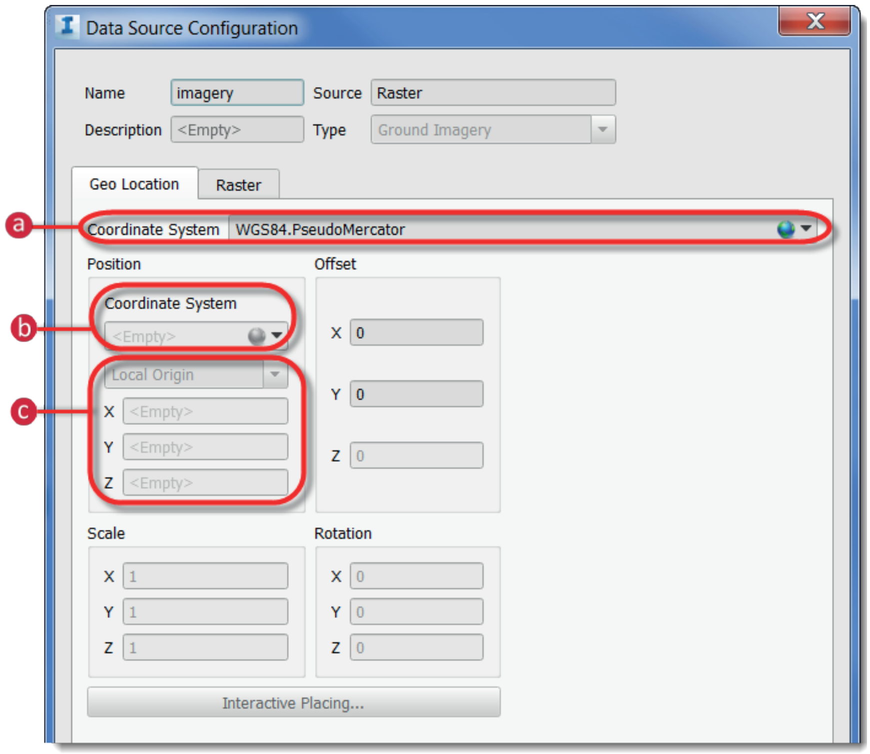
Civil 3D

According to the software manual, Civil 3D includes a geographic coordinate system library.[1] A screenshot of it is shown below.



Infraworks

According to the software manual, Infraworks includes GCS.[2] In fact, it is impossible to model in Infraworks without determining a GCS (Geographic Coordinate System) or in more plain terms, a real world location. This is the main way Infraworks' coordinate system differs from other software.



Picture of Geo Location settings from Infraworks' manual.[3]

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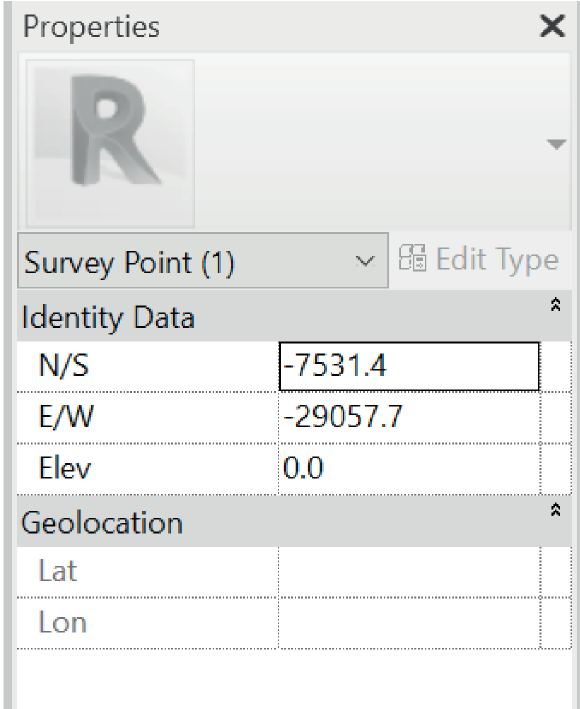
1 Knowledge.autodesk.com. (no date). Coordinate System Library. http://help.autodesk.com/view/CIV3D/2018/ENU/?guid=GUID-8DFA82DB-89BA-4145-9C58-72B0CA761CD8 Accessed 28.7.2019.

2 Knowledge.autodesk.com. (no date). To specify geolocation settings. https://help.autodesk.com/view/INFM-DR/ENU/?guid=GUID-ADC0B758-7054-4A4F-A30D-46F0DA6901E8 Accessed 28.7.2019.

3 Knowledge.autodesk.com. (no date). To specify geolocation settings. https://help.autodesk.com/view/INFM-DR/ENU/?guid=GUID-ADC0B758-7054-4A4F-A30D-46F0DA6901E8 Accessed 28.7.2019.

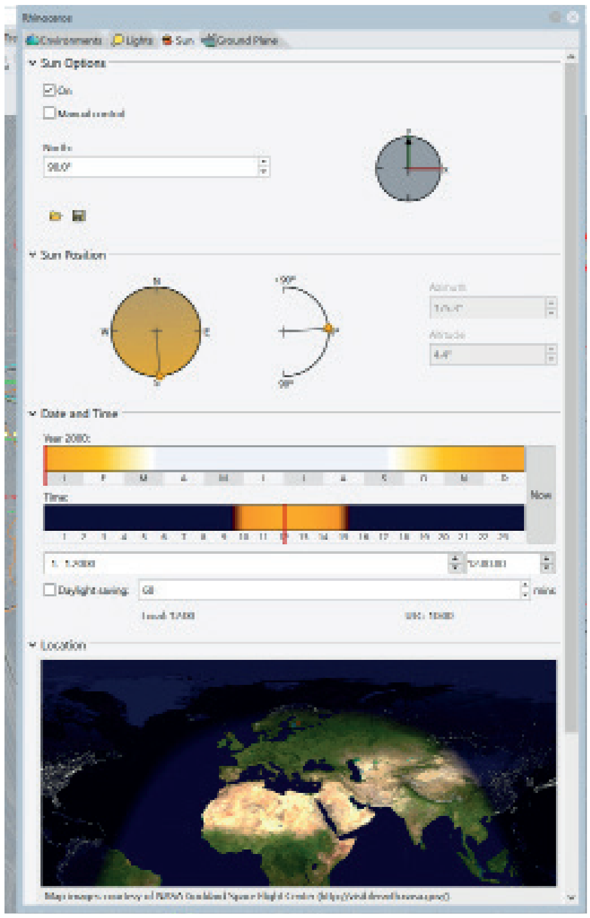
Revit



According to the software manual, Revit uses a survey coordinate system to locate a model geographically.[1] However, this system is fundamentally different from the coordinate system libraries in both Civil 3D and Infraworks. In order to do 3D modeling in Revit, the file that is in a Finnish coordinated system has to be detached from the predetermined coordinate system and be moved to the origin point, and the coordinates be determined with a survey point instead.[2]

To the right is pictured the Survey Point's properties. The coordinates can be defined here manually in any chosen coordinate system. The correct coordinates must be found from a project file that is already in the chosen coordinate system. More about defining the survey point is explained in Revit's software manual: http://help.autodesk.com/view/RVT/2019/ENU/?guid=GUID-595C5BC0-EE23-4C6E-AD0C-9BCBF6598615

Rhino 3D



As Rhino is intended for product design, thus geographic location not being necessary information, it only has the User Coordinate System (at least without using Grasshopper or plugins). It is possible to determine a geographic location for rendering shadows, but this does not allow the use of Finnish coordinate systems or transformation between coordinate systems. The sun settings that use a geographic location and time value are pictured to the right.

1 Knowledge.autodesk.com. (no date). About the Survey Point. http://help.autodesk.com/view/RVT/2019/ENU/?guid=GUID-81CB0DD4-DF6E-43A3-AADA-DABC5ED30C6F Accessed 28.7.2019.
2 Knowledge.autodesk.com. (no date). About Coordinate Systems. http://help.autodesk.com/view/RVT/2019/ENU/?guid=GUID-E67ED082-2556-475B-84A7-4605329F612F Accessed 28.7.2019.

Sketchup

Only UCS is used while modeling in Sketchup. However, there is the option to use a geolocation system that is based on Google Earth. This system is able to extract terrain geometry and imagery from the Google Earth 3D model. However, it does not allow the use of Finnish coordinate systems or transformation between coordinate systems. Below is pictured a terrain model extracted from Google Earth, along with the satellite image.

1.1. Verdicts

1. Setting up the 3D model	Civil 3D	Infraworks	Revit	Rhino 3D	Sketchup Pro
1.1. Geographic coordinate systems, geolocation	Coordinate system library	Coordinate system library. Cannot model without defining a coordinate system.	Survey coordinate system. No coordinate system library.	Geolocation for rendering shadows. No coordinate system library.	Google Earth geolocation. No coordinate system library.

Good (5-4 pts)
Intermediate (3-2 pts)
Barely functional / Non-functional (1-0 pts)
Notes

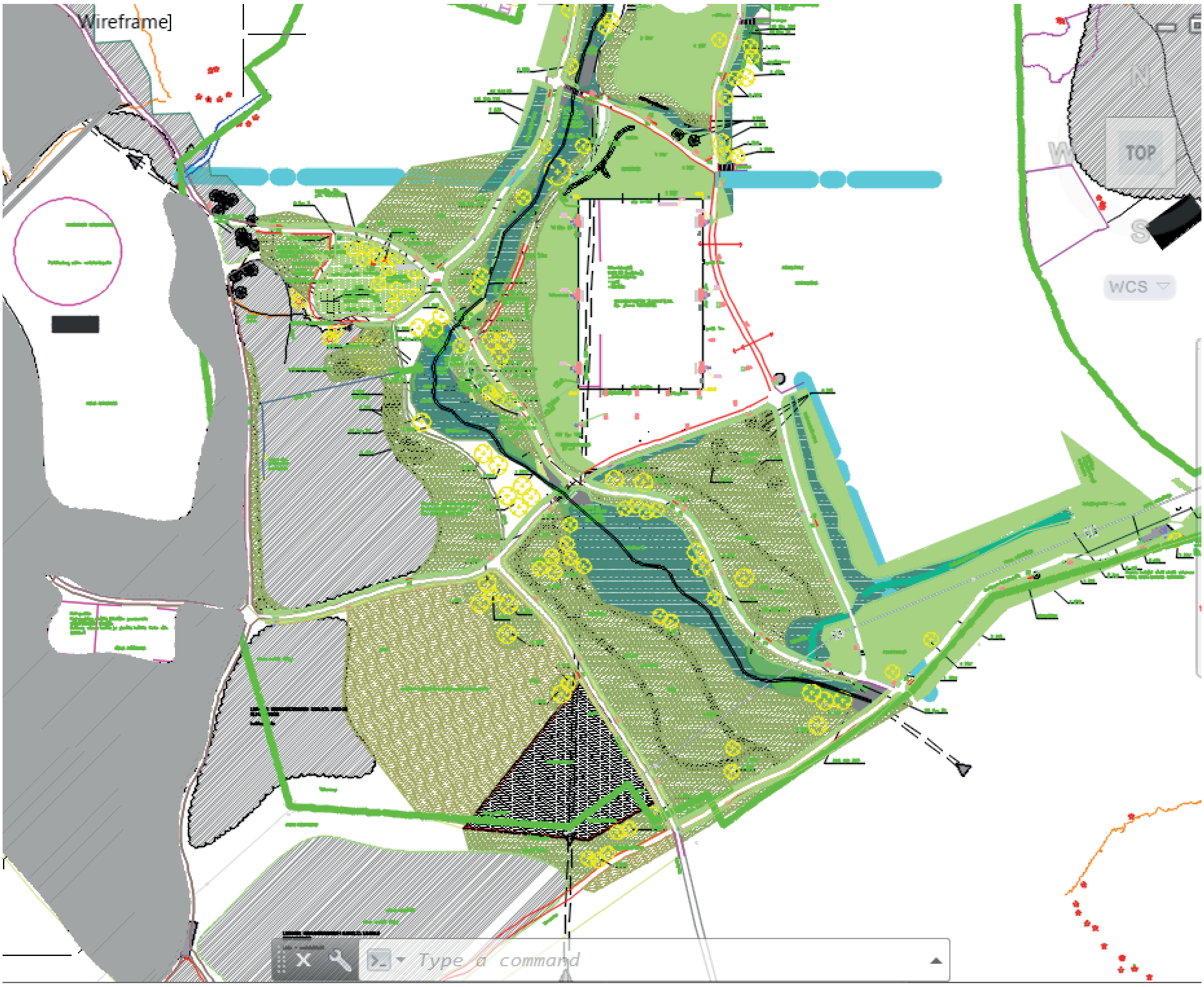
Scoring each sub-task will be done in the summary at the end of the software comparison, and represents a weighted average value concerning the whole subtask rather than an added value.

1.2. Importing the site plan

The site plan of the Skanssi park must be placed in the 3D model, so that the new landmassing can be placed in relation to the design. Therefore the software should be able to open the file format the site plan is in (DWG). The site plan should also be able to be placed in coordinates.[1]

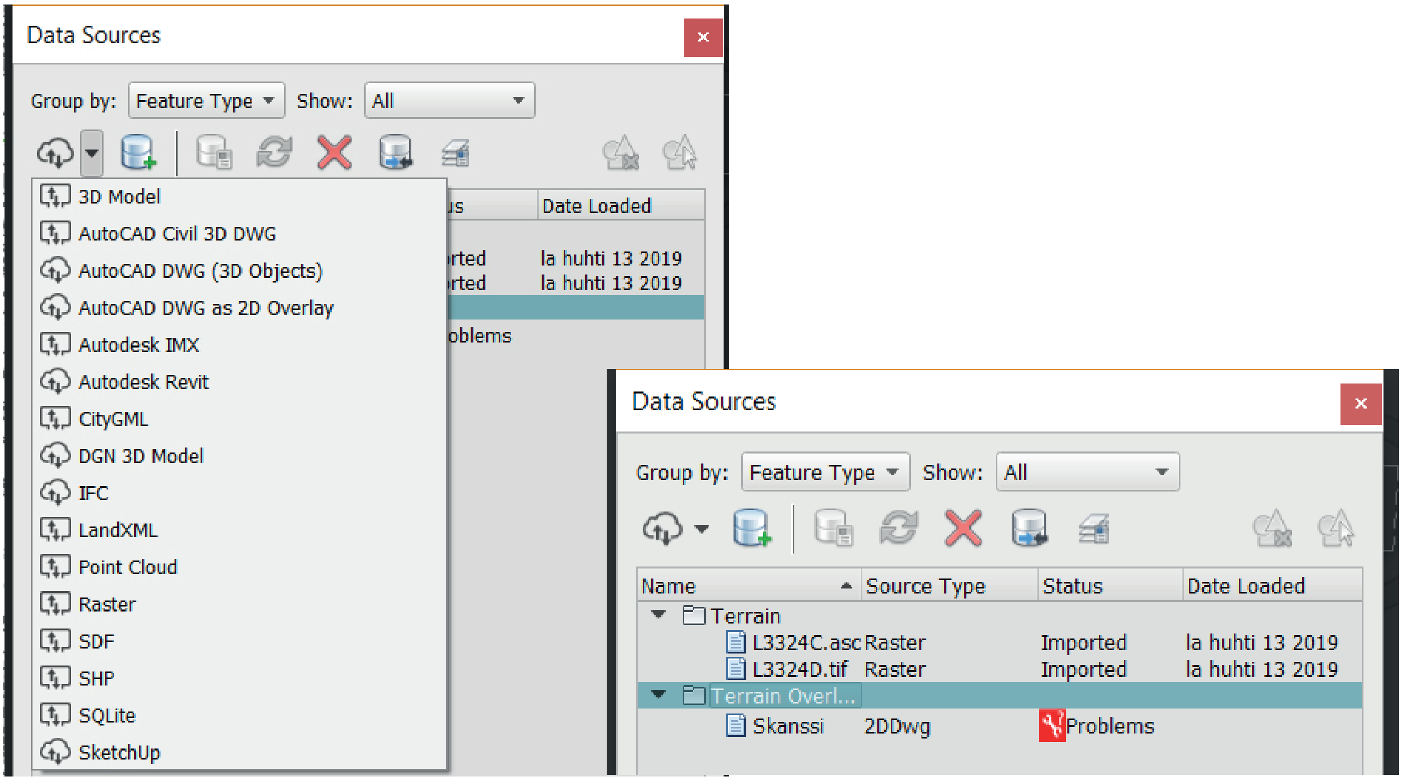
Civil 3D

Using the Skanssi.dwg that has been placed in the Finnish coordinate system ETRS89.FinlandGK-23 with AutoCAD Map 3D 2018 poses no problems, seeing that AutoCAD Map 3D and Civil 3D are fully compatible with each other. The DWG, when opened, looks exactly the same as it would in AutoCAD Map 3D.



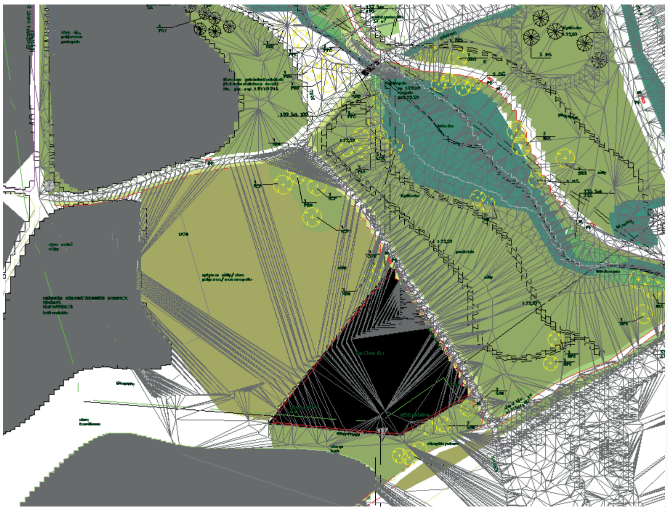
1 Note that the plan has been placed into the coordinate system using AutoCAD Map 3D, which is not possible using basic AutoCAD.

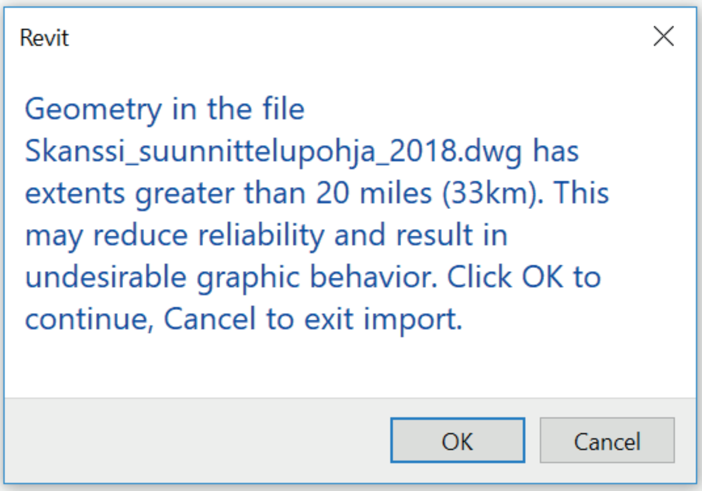
Infraworks



In theory DWGs can be imported into Infraworks, as shown in the image on the left. However, in practise this rarely works, as seen in the picture on the right that shows that there are problems with the DWG file. It is better to convert the objects in the DWG into SHP format, which is commonly used by GIS software such as ArcGIS.

Revit

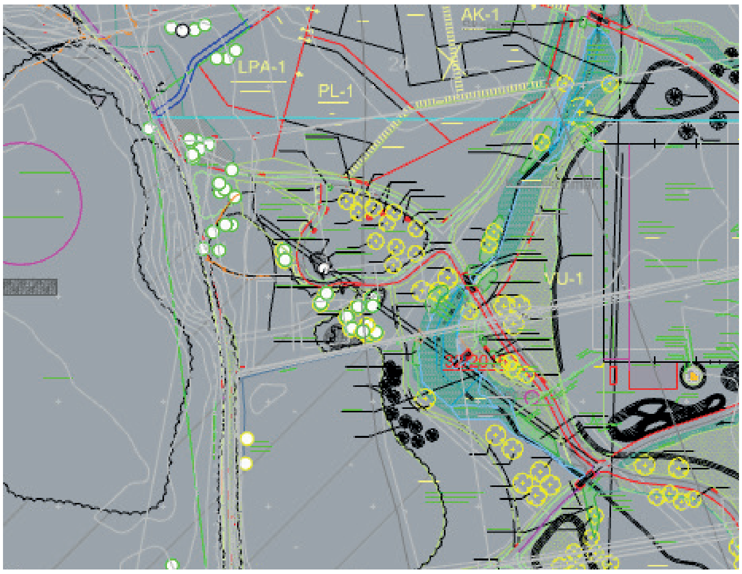




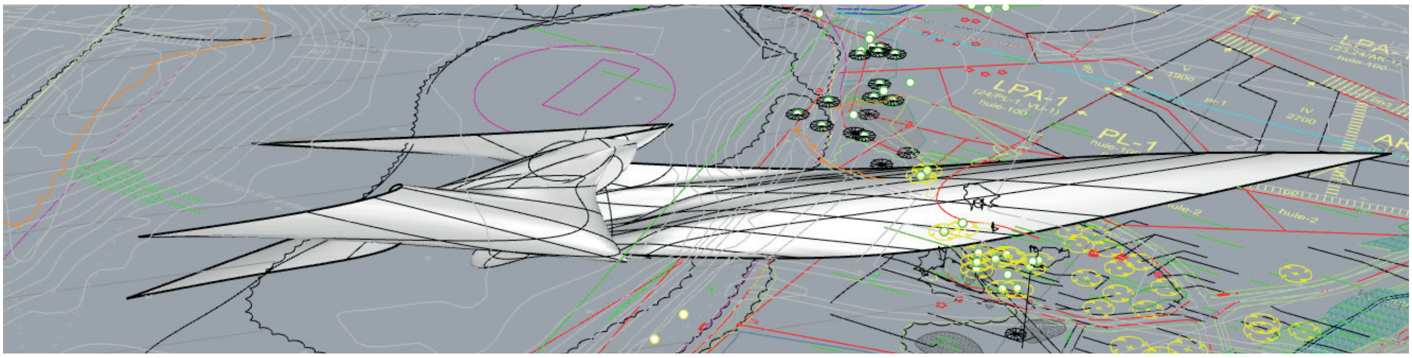
The DWG can be opened in Revit, but above is shown the message that appears. Attempting to use the DWG file in a geographic coordinate system may cause errors due to the large project extents.

More about the maximum distance limit in Revit's manual:
http://help.autodesk.com/view/RVT/2019/ENU/?guid=GUID-3F79BF5A-F051-49F3-951E-D3E86F51BECC

Rhino 3D



The DWG can be opened in Rhino as shown to the right, but the coordinate system may cause problems while doing 3D modeling, as shown in the image below. The shape was intended to be that of a hill. This problem can be caused by a similar problem as in Revit, in that the project extents are too large. The set-up of the X-Y plan in the UCS can also cause problems. In some software the Y-axis is used to indicate height instead of the Z-axis as in Rhino. However, Z-axis is used for height both in AutoCAD and Rhino, so this is unlikely to be the source of the problem in this case.



Sketchup

Sketchup crashes while attempting to open Skanssi.dwg. After saving the DWG in an older format, importing continues to be unsuccesful. After moving the ground plan into origin, importing continues to be unsuccesful. The problem may be with importing blocks such as city furniture or sports equipment. Due to these problems, olnly carefully selected parts of the DWG will be used.

1.2. Verdicts

1. Setting up the 3D model	**Civil 3D**	**Infraworks**	**Revit**	**Rhino 3D**	**Sketchup Pro**
1.2. Importing the site plan	Yes, along with the coordinate system.	In theory yes, but in practise no. Can be imported in SHP format instead.	Yes, but the project extents are too large with the Finnish coordinate system used. However, can be used after moving to origin.	Yes, but most likely the project extents are too large with the Finnish coordinate system used. However, can be used after moving to origin.	No, crashes while opening the Skanssi.dwg that is set in the Finnish coordinate system. However, smaller fragments can be imported.

1.3. Importing the existing terrain model

Before the volume of the placed landmass can be calculated, a 3D model of the existing terrain must be placed. In Finland, Maanmittauslaitos (MML) provides an online service where terrain models can be downloaded: https://www.maanmittauslaitos.fi/asioi-verkossa/avoimien-aineistojen-tiedostopalvelu

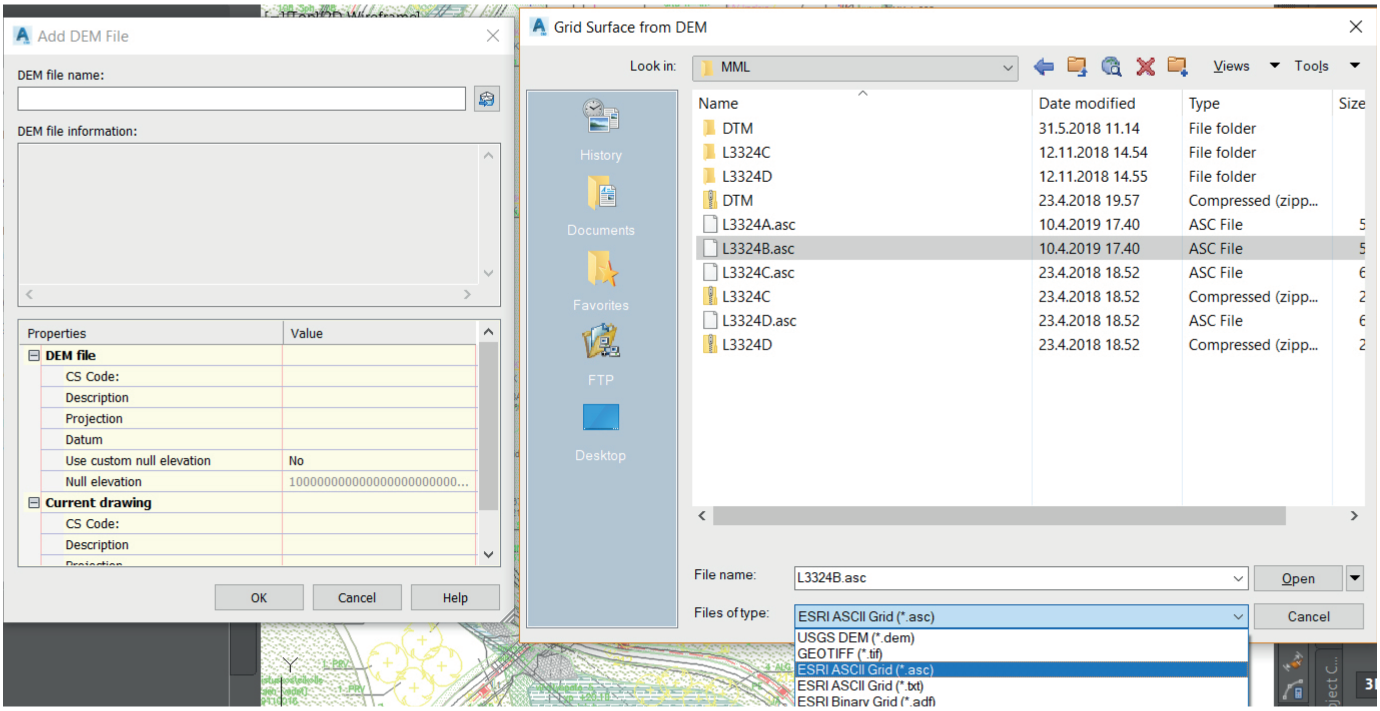
The MML terrain models are provided in ASC and TIFF file formats.The ASC files are in Esri ASCII grid format, which has its own requirements for the structure of the file. [1] This means that a software that can open ASC files may not be able to open the ASCII grid file because it is in a different format. Similarly, the TIFF file is a GeoTIFF, meaning that it "contains additional tags that provide projection information for that image as specified by the GeoTIFF standard" compared to a normal TIFF. [2]

The laser scanning files provided by MML (in LAZ file format) include surface objects such as vegetation and buildings, and were used by MML to create the terrain models. [3] Therefore it is advisable to use the preprocessed terrain models instead of the laser scans whenever possible (unless you specifically want to use the vegetation, buildings, etc. included in the point cloud data). Therefore in this experiment mainly the preprocessed terrain models will be used instead of the point cloud data.

The plan file made in AutoCAD Map 3D is set in the ETRS89.FinlandGK-23 coordinate system. The files downloaded from Maanmittauslaitos are set in ETRS89.TM-35/Fin coordinate system. This means that the MML terrain file has to be converted to the coordinate system that is used by the host file. Or, if the software does not use geographic coordinate systems, it has to be located otherwise.

Civil 3D

Civil 3D has the ability to create a surface model from both ASCII grid and GeoTIFF file formats, making it ideal for opening the terrain models from MML. Below is shown the dialogue for opening either file format. In Civil 3D they are classified as DEM files.



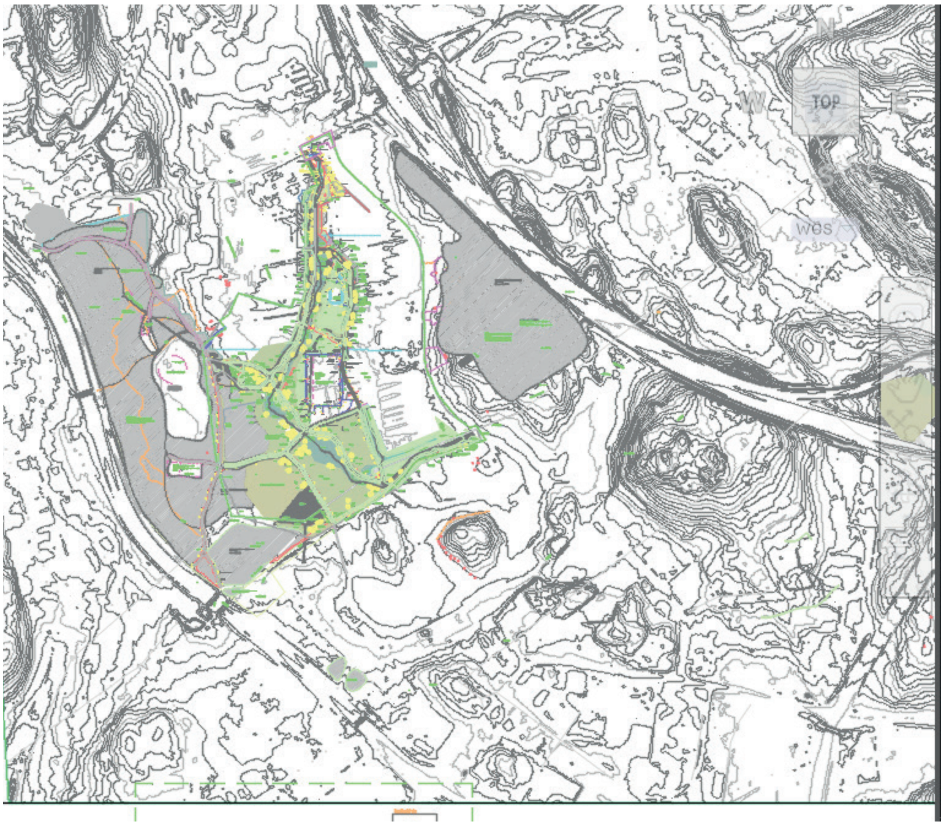
For the coordinate transformation to be successful, the Skanssi work file must first be set to be in ETRS89.FinlandGK-23. Then the MML terrain model can be defined to be in ETRS89.TM-35/Fin. It will be positioned in the correct location automatically.

1 Resources.esri.com. (no date). ESRI ASCII Raster format. http://resources.esri.com/help/9.3/arcgisengine/java/GP_ToolRef/spatial_analyst_tools/esri_ascii_raster_format.htm

2 Manifold.net. (no date). TIF, TIFF, GeoTIFF. http://www.manifold.net/doc/mfd9/tif,_tiff,_geotiff.htm Accessed 28.7.2019.

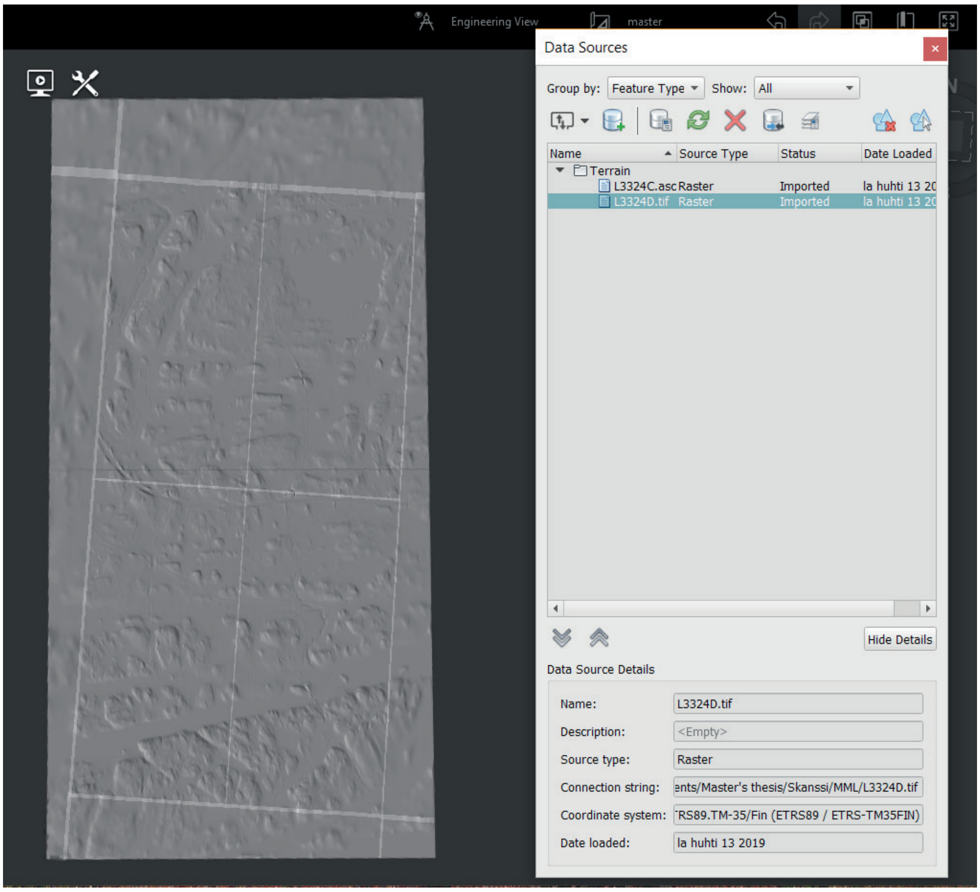
3 Maanmittauslaitos.fi. (no date). Laserkeilausaineisto. https://www.maanmittauslaitos.fi/kartat-ja-paikkatieto/asiantuntevalle-kayttajalle/tuotekuvaukset/laserkeilausaineisto Accessed 28.7.2019.

However, it must be noted that the MML files are quite heavy to use, and slow down Civil 3D considerably. This can be minimised by cropping the terrain model to the ground plan extents. To th right is shown the uncropped terrain model.



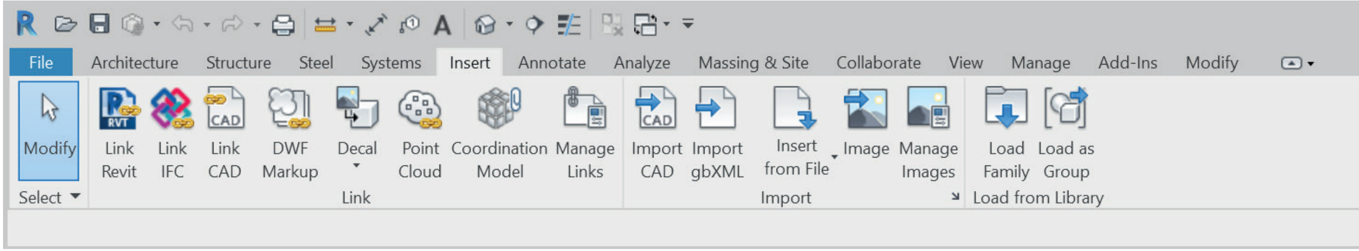
Infraworks

Infraworks can create a surface model from both ASCII grid and GeoTIFF file formats. The picture beside shows both file formats imported into Infraworks.



Revit

Revit can open DWG, IFC and point cloud file formats, but it cannot open the terrain models provided in ASC and TIFF file formats. Below are shown the import options.

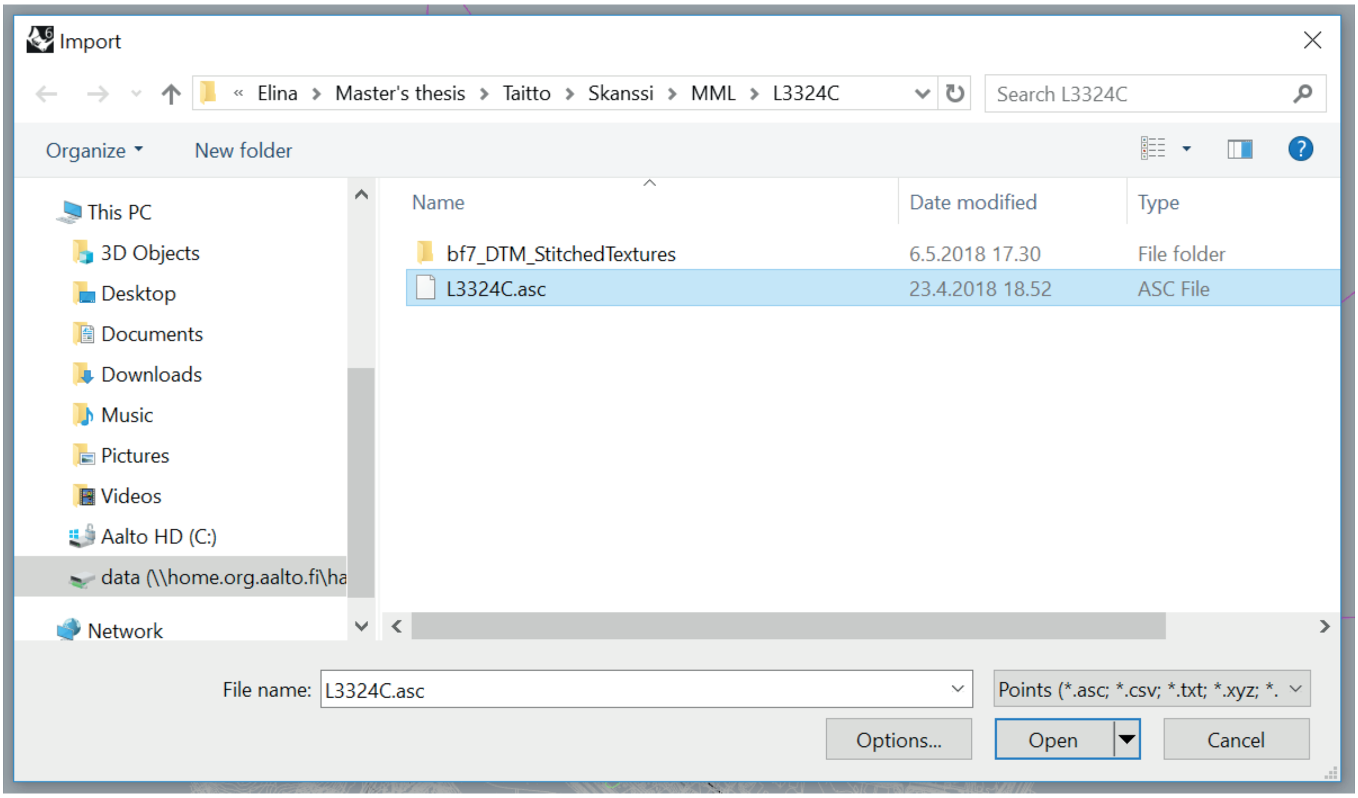


A point cloud file (LAZ) can be opened, but only after converting to RCP or RCS. In order to convert LAZ into RCP an external software called Autodesk ReCap must be used. However, it would be preferrable to be able to open either the ASC or TIFF file.

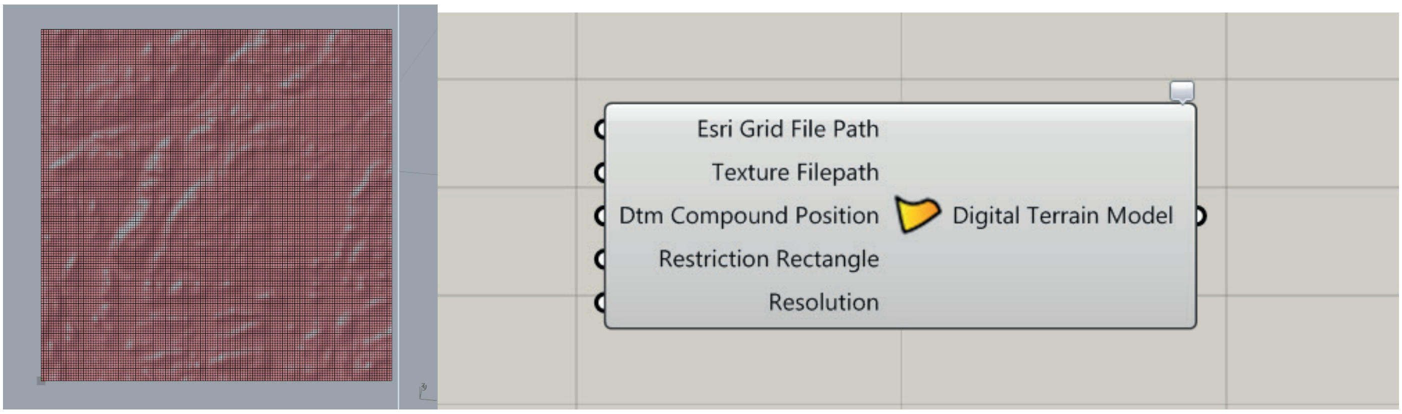
“The support for raw point cloud files was removed from Revit 2019. The reason this was done, is because previous versions of Revit had its own “indexer” in order to open the raw point cloud files directly. The indexer in ReCap has better performance in a number of ways. It was decided maintaining an inferior indexer inside of Revit was a duplication of effort and did not make sense when the ReCap indexer could do a better job and would only have to be maintained in one place. “ [1]

Rhino 3D

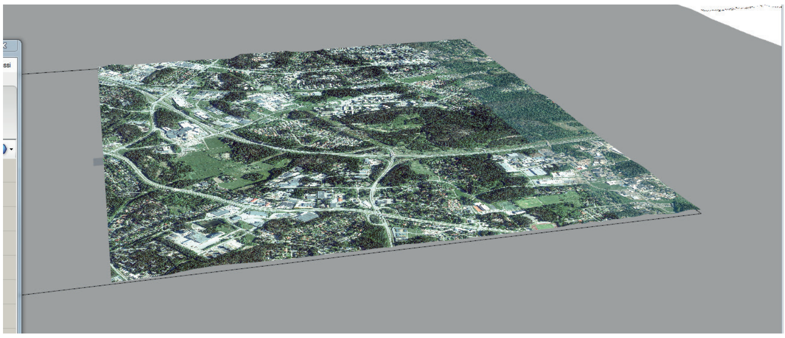
Rhino can open ASC files with the “Import” command. However, it does not recognize the ASCII grid file type specifically. A grasshopper plugin must be used in order to open an ASCII grid or GeoTIFF file.

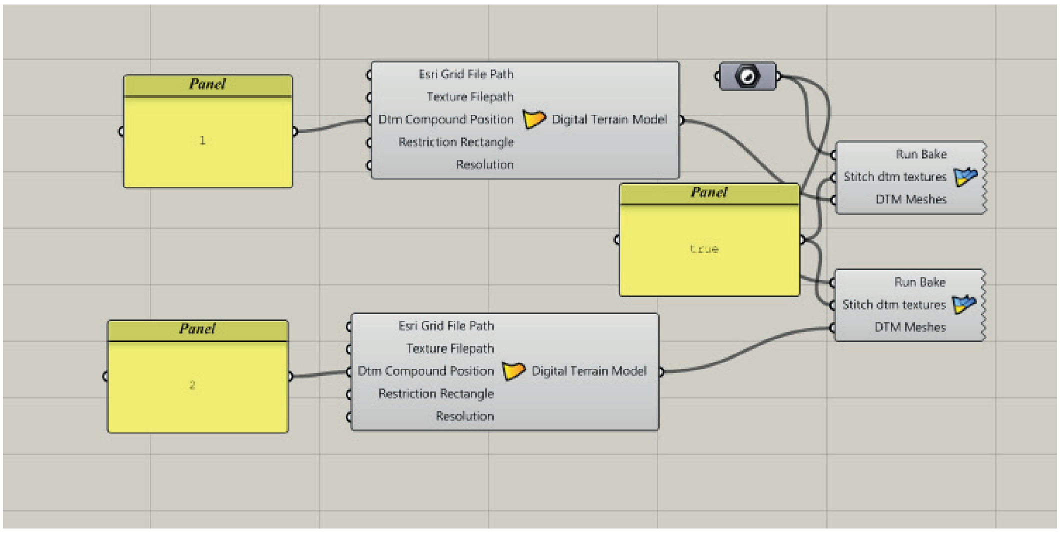


1 Knowledge.autodesk.com. (no date). Revit 2019 insert Point Cloud. http://help.autodesk.com/view/RVT/2019/ENU/?caas=caas/discussion/t5/Revit-Architecture-Forum/Revit-2019-insert-Point-Cloud/td-p/7993304.html Accessed 28.7.2019.



The ASCII grid file can be imported with the DTM plugin in Grasshopper, as shown above. Note that an aerial photo must be used to locate the design area in the model, because a coordinate system cannot be used, as shown below. The DTM plug-in can be downloaded here: https://www.food4rhino.com/app/dtm-digital-terrain-mesh



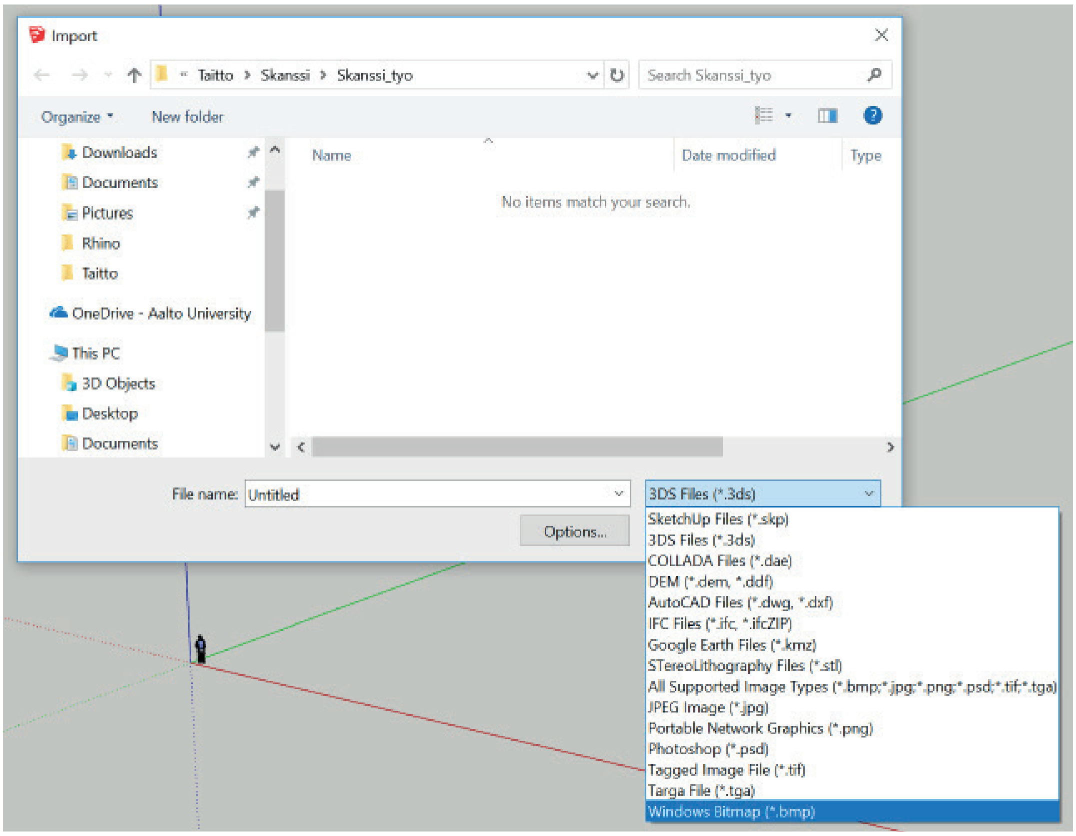


1.3. Verdicts

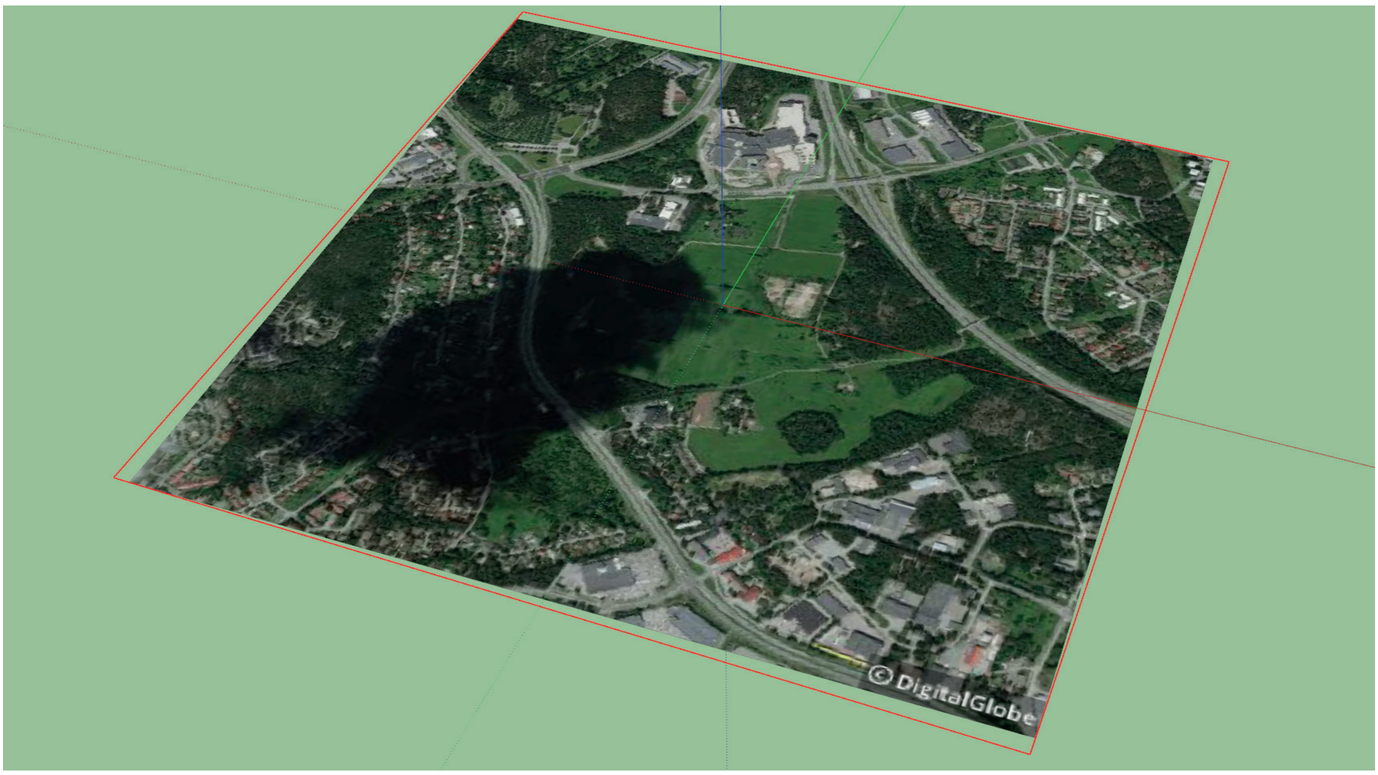
1. Setting up the 3D model	**Civil 3D**	**Infraworks**	**Revit**	**Rhino 3D**	**Sketchup Pro**
1.3. Importing the existing terrain model from MML (ASCII grid, GeoTIFF and LAZ file formats)	Can open ASCII grid, GeoTIFF.	Can open ASCII grid, GeoTIFF.	Can open LAZ after being converted into RCP in Autodesk ReCap.	Can open ASC, but not ASCII grid, GeoTIFF or LAZ. However, can open ASCII grid with Grasshopper plugin.	Cannot open ASCII grid, GeoTIFF or LAZ. However, Google Earth terrain model can be used.

Sketchup:

Sketchup cannot import ASCII grid, GeoTIFF or LAZ. Below it is shown which file types can be imported.



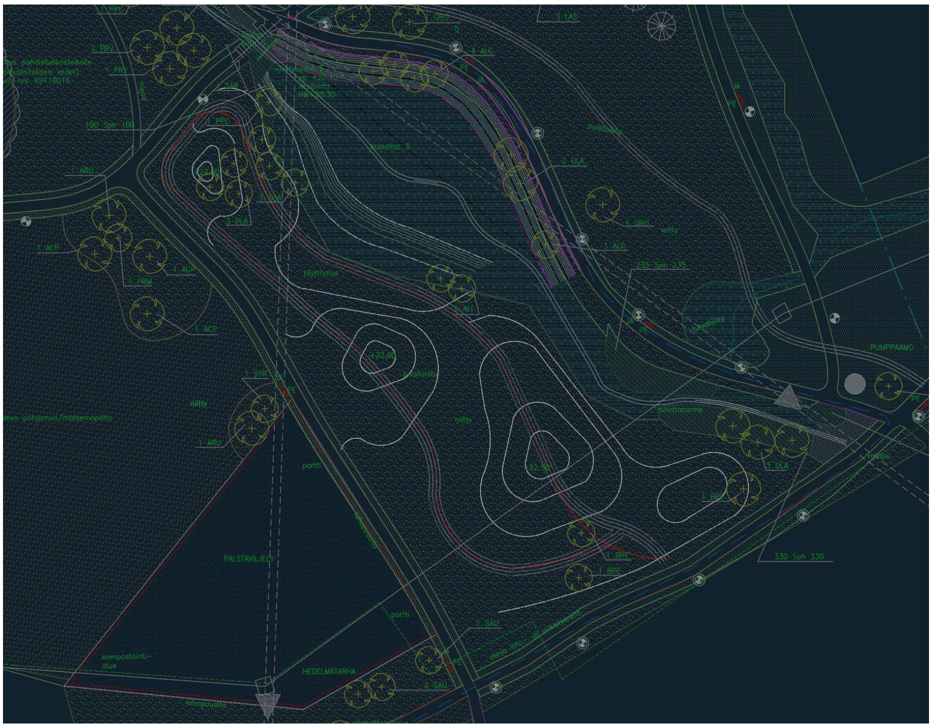
However, there is the option to use the Google Earth -based geolocation system. This system is able to extract terrain geometry and imagery from the Google Earth 3D model. But it does not allow the use of the MML terrain models that have higher accuracy (2 m).



2.1. 3D modeling from contours

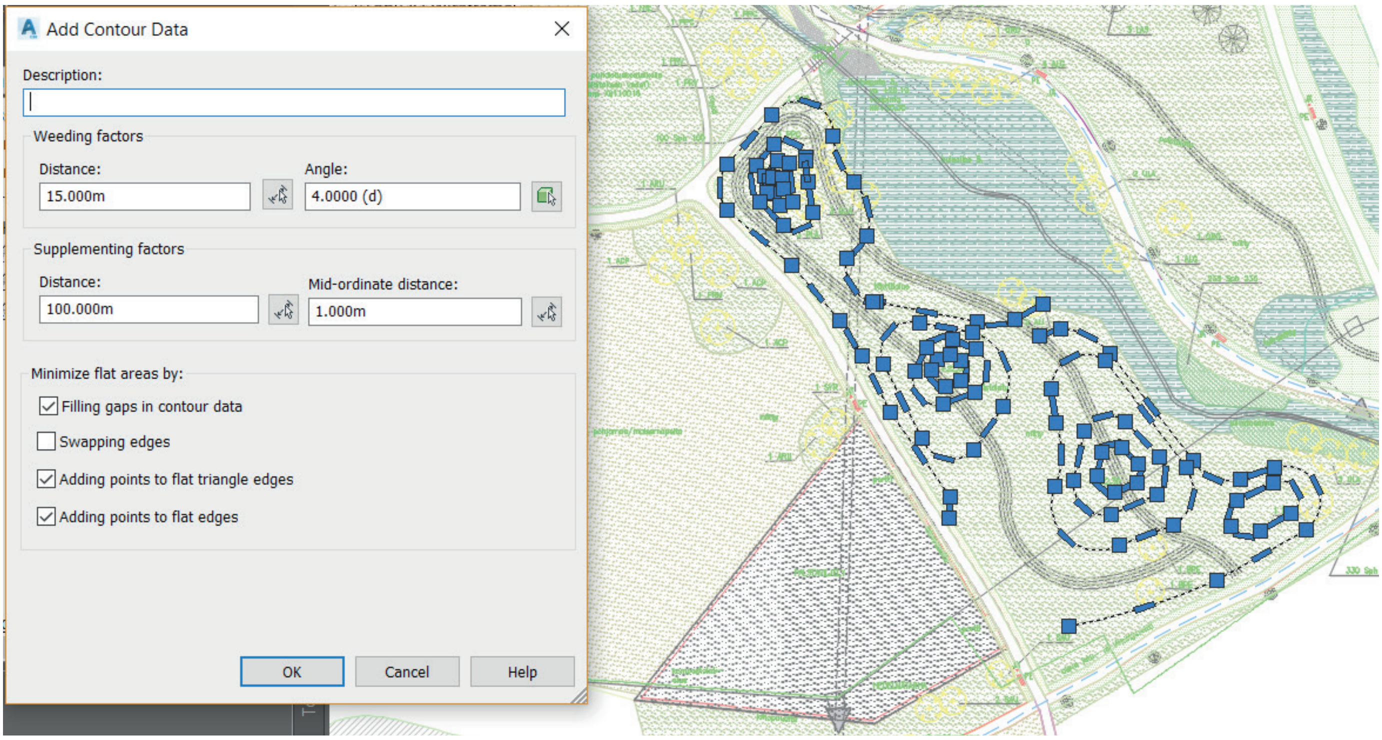
In white are shown the contours that were drawn in AutoCAD Map 3D. The contours have set height values taking into account the design task: added landmass can be maximum +1,5m from current terrain level. Spatial qualities were also taken into account while trying to achieve a larger volume of landmass.

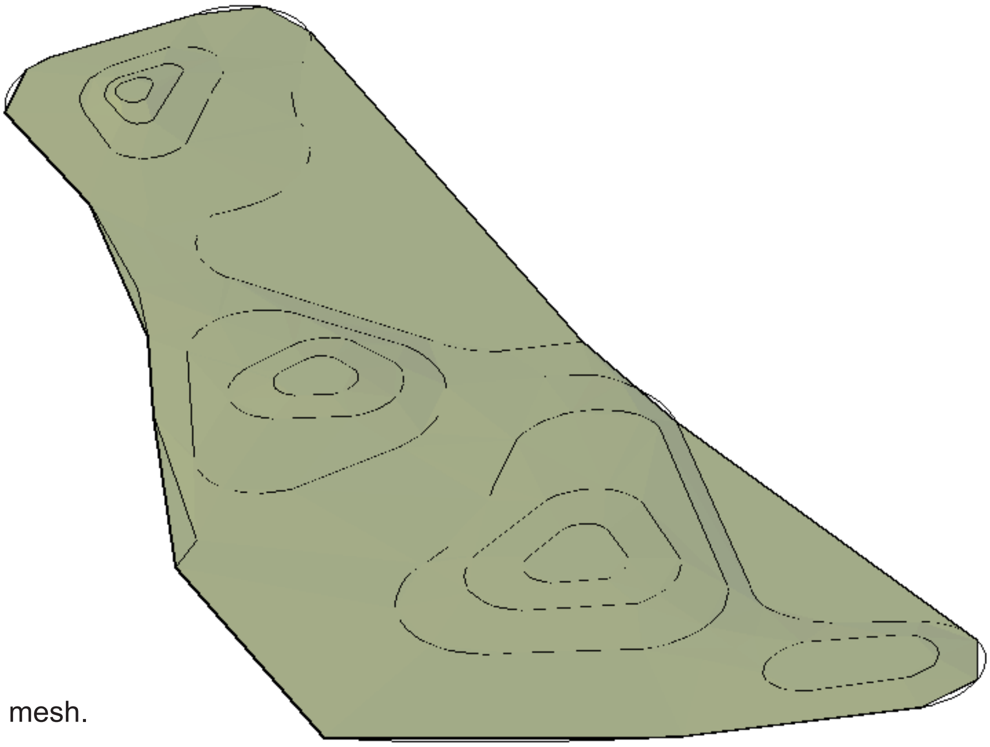
It should be possible to create a 3D model using contours, as designing landforms with contours is a common method in landscape architecture.



Civil 3D:

The 3D model is made by creating a new surface, and adding the contours to define it. This results in a mesh surface. Below is shown a screenshot of the “Add Contour Data” dialog.

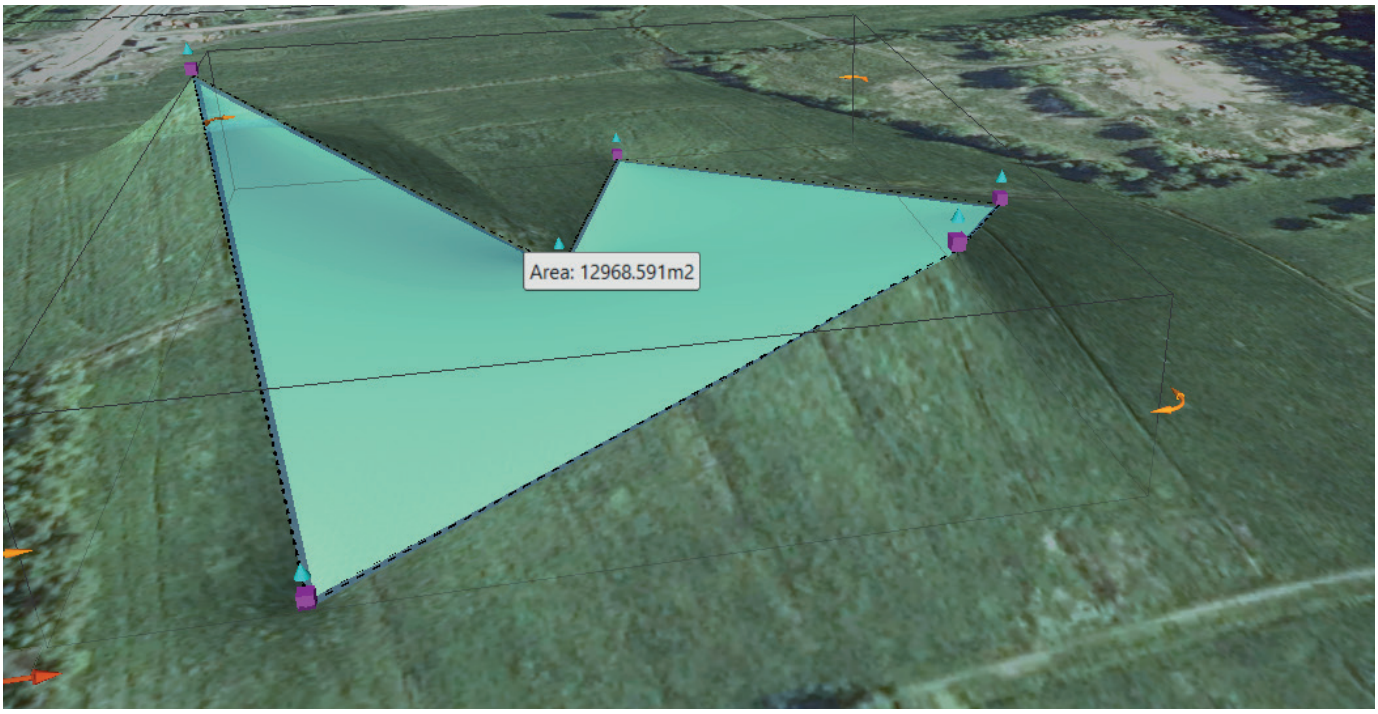




Beside is shown the resulting mesh.

Infraworks:

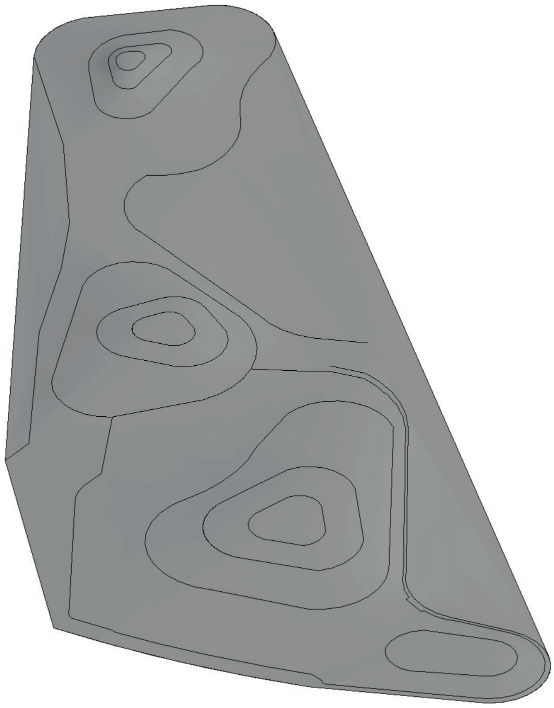
Infraworks is mainly made for compiling and representing premade 3D models instead of 3D modeling, therefore it is not possible to make a 3D model from contours in Infraworks. It is, however, possible to transform the MML terrain with the "Coverage" tool, but this is very limited.[1] Only the vertices of the coverage area can be moved vertically, as shown below. The ready 3D model should be imported from another software.



1 Knowledge.autodesk.com. (no date).To add or modify coverage areas or create a hole in terrain. https://help.autodesk.com/view/INFMDR/ENU/?guid=GUID-2DDFAD4F-C5E8-488A-8EE6-6F006F58896F Accessed 4.8.2019

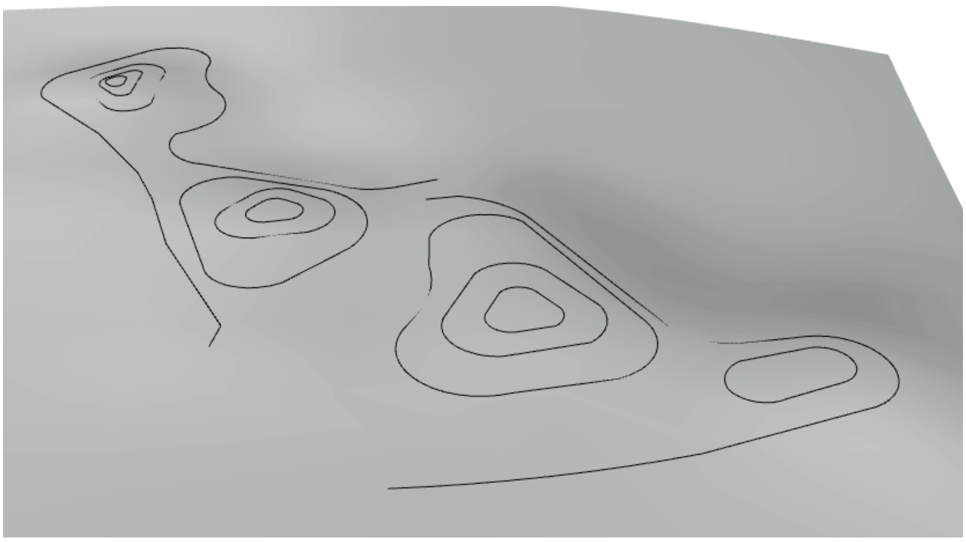
Revit:

The contours can be imported from a DWG file, and then a toposurface can be created from the import. This results in a mesh surface



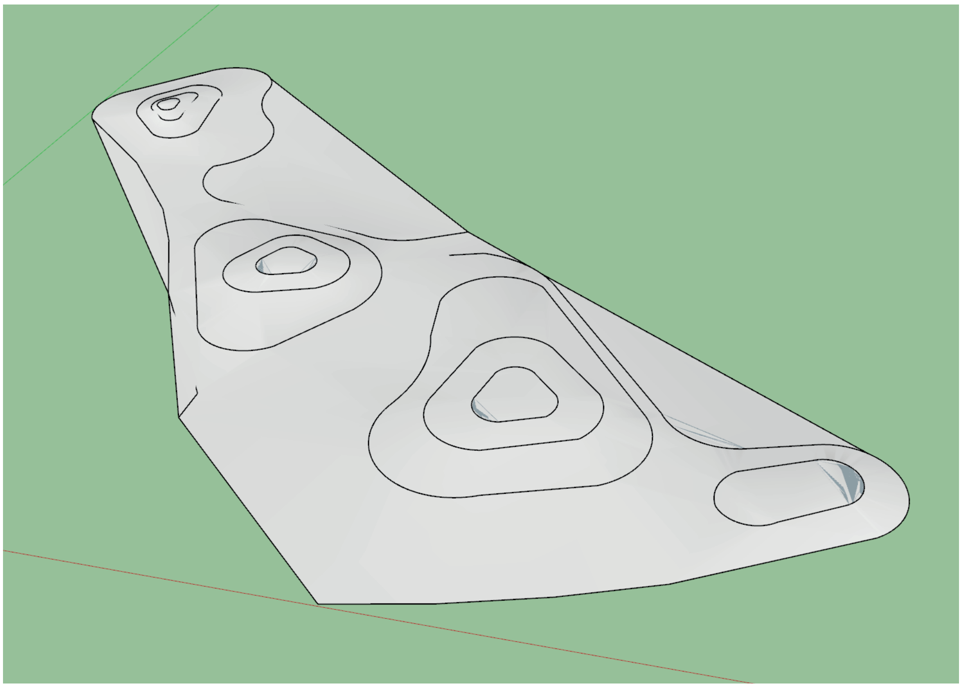
Rhino 3D:

A mesh with similar accuracy as other software can be created with MeshPatch. However, for editing in Rhino it needs to be a NURBS surface - using eg. Patch tool. Patch gives inaccurate results but with adjustments it can be improved.



Sketchup:

Sketchup Pro must be used for importing contours from DWG, as the free version does not support DWGs. After exploding the exported DWG into lines, a mesh can be created with one click from the contour lines using the Sandbox tools.

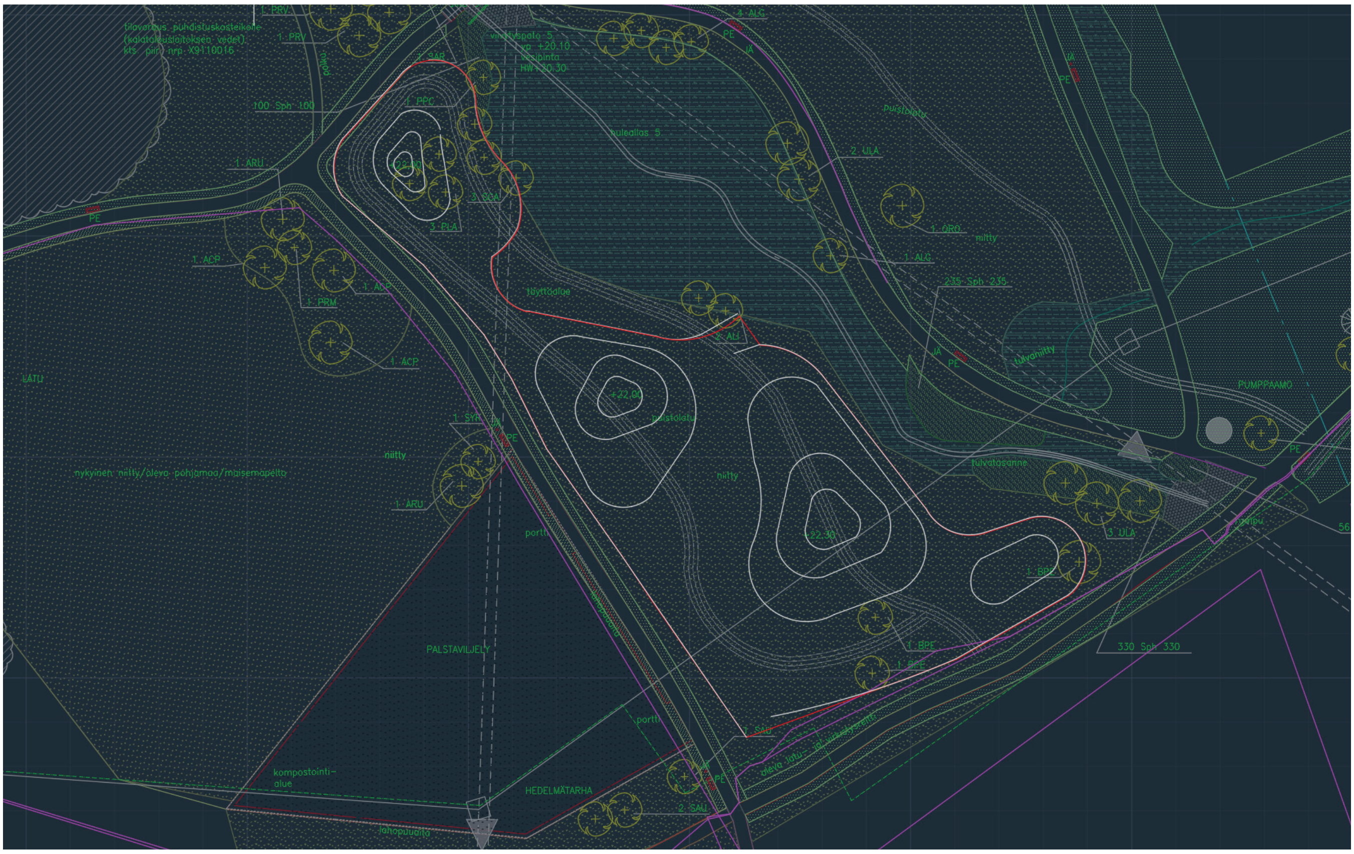


2.1. Verdicts

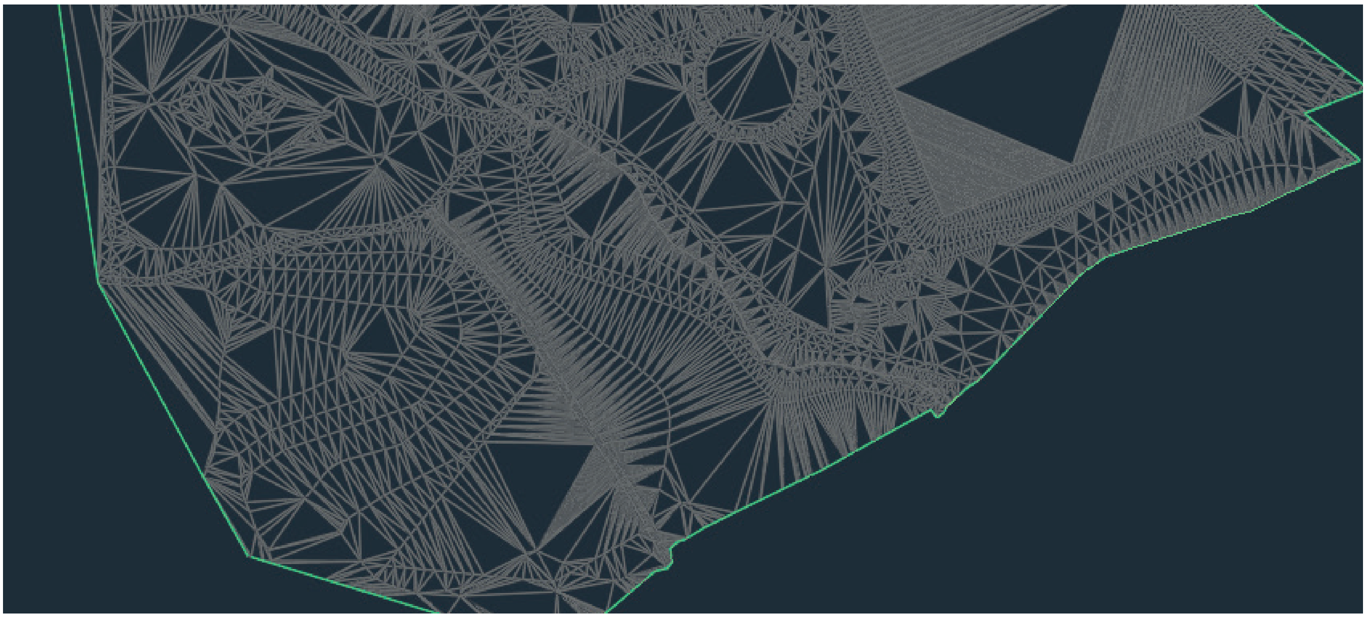
2. Landforms	**Civil 3D**	**Infraworks**	**Revit**	**Rhino 3D**	**Sketchup Pro**
2.1. 3D modeling from contours	Yes, using meshes.	No. But some primitive terrain modeling is possible with the Coverage tool.	Yes, using meshes.	Yes, using meshes or preferrably NURBS.	Yes, using meshes. Note that Sketchup Pro must be used to import DWGs.

2.2. Connecting the designed surface to surrounding terrain

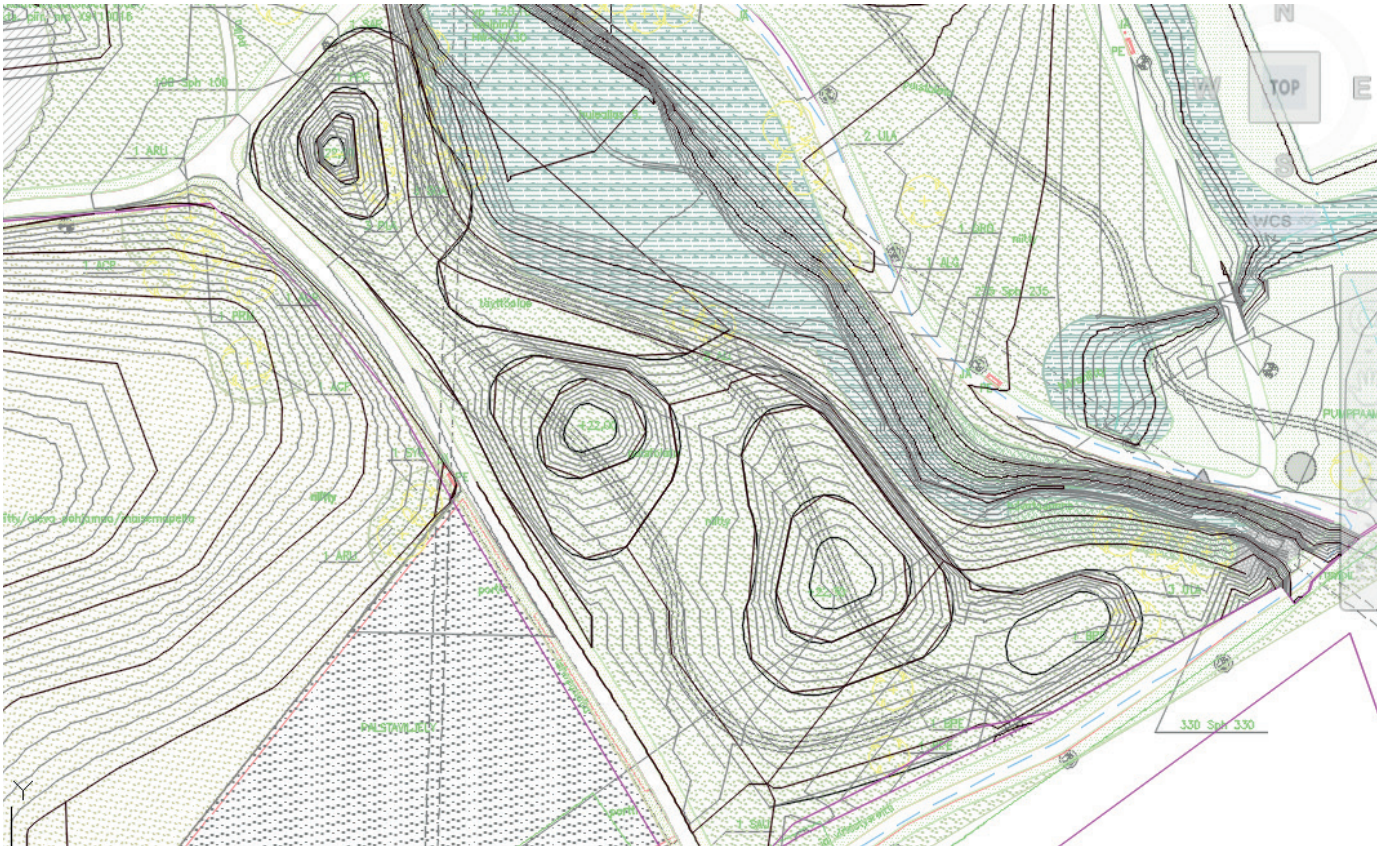
For a smooth transition, the newly designed landform will be connected to the existing landforms. To be able to connect the contours to the terrain more easily, some adjustment were made on the previously shown DWG contours, as seen below.



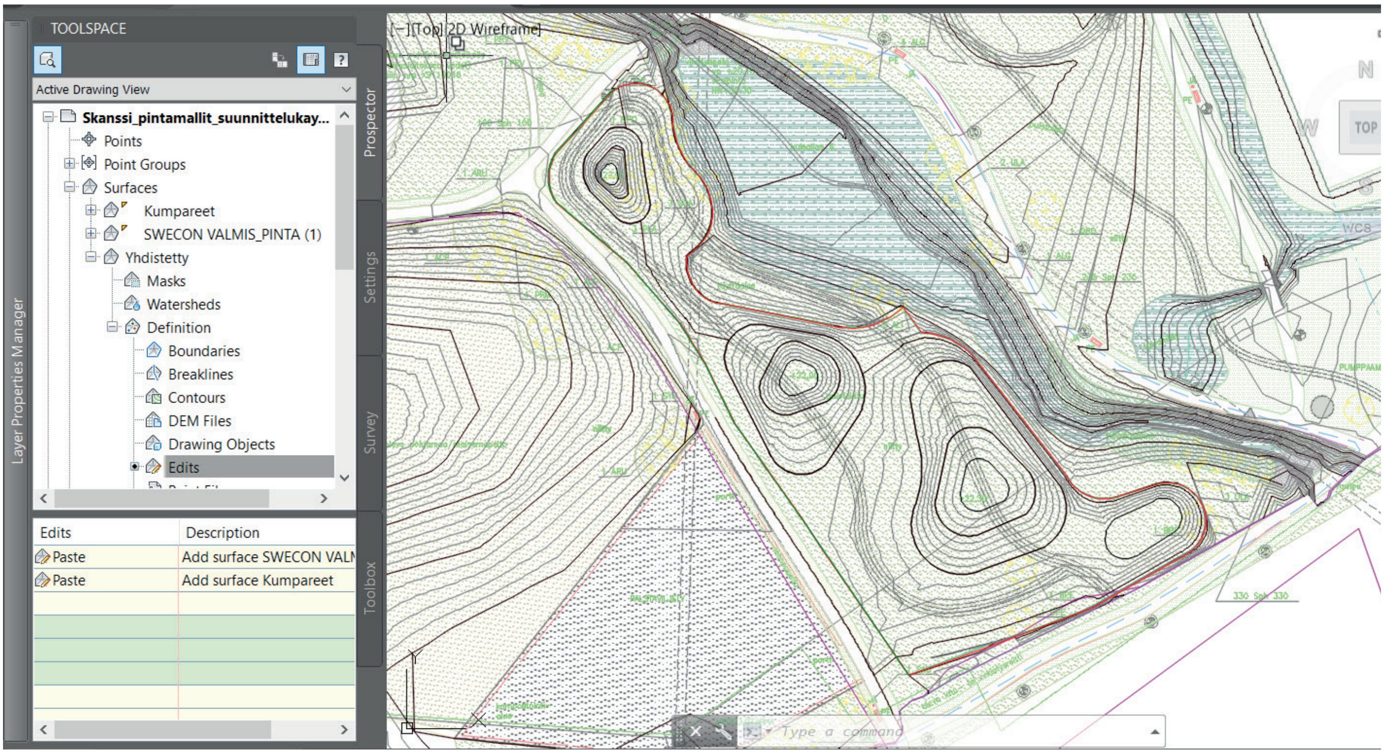
The newly designed landforms will be connected to the surrounding designed landforms (previously modelled by Sweco in Civil 3D). However, the volume calculation will be done compared to the current terrain as acquired from MML. Below is shown Sweco's Civil 3D surface converted into a DWG mesh.



Civil 3D:



The contours of the designed landforms and Sweco’s surface are shown overlapping above.



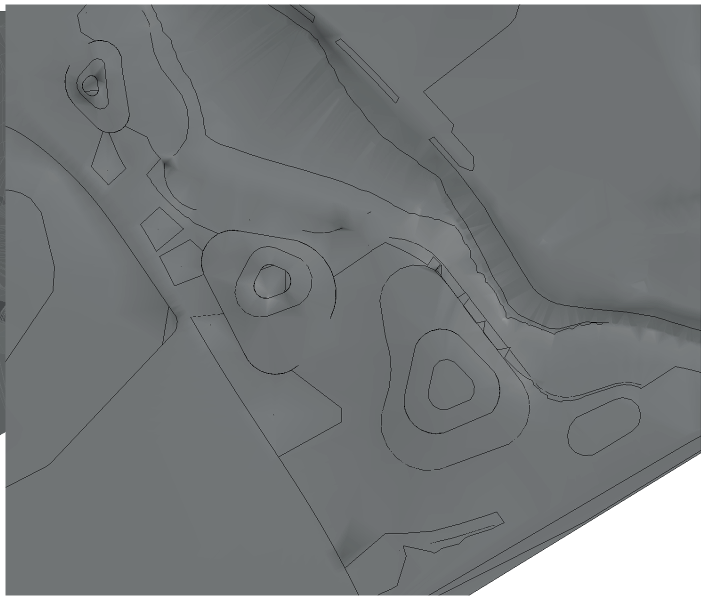
The two surfaces can be merged simply by pasting them both into a new surface in Edit. The resulting transition is somewhat smooth, but can be improved by further adjusting the edge contours. (It is possible to acquire the heights for the edge of the designed landforms from Sweco’s surface to ensure a smooth transition.)

Infraworks:

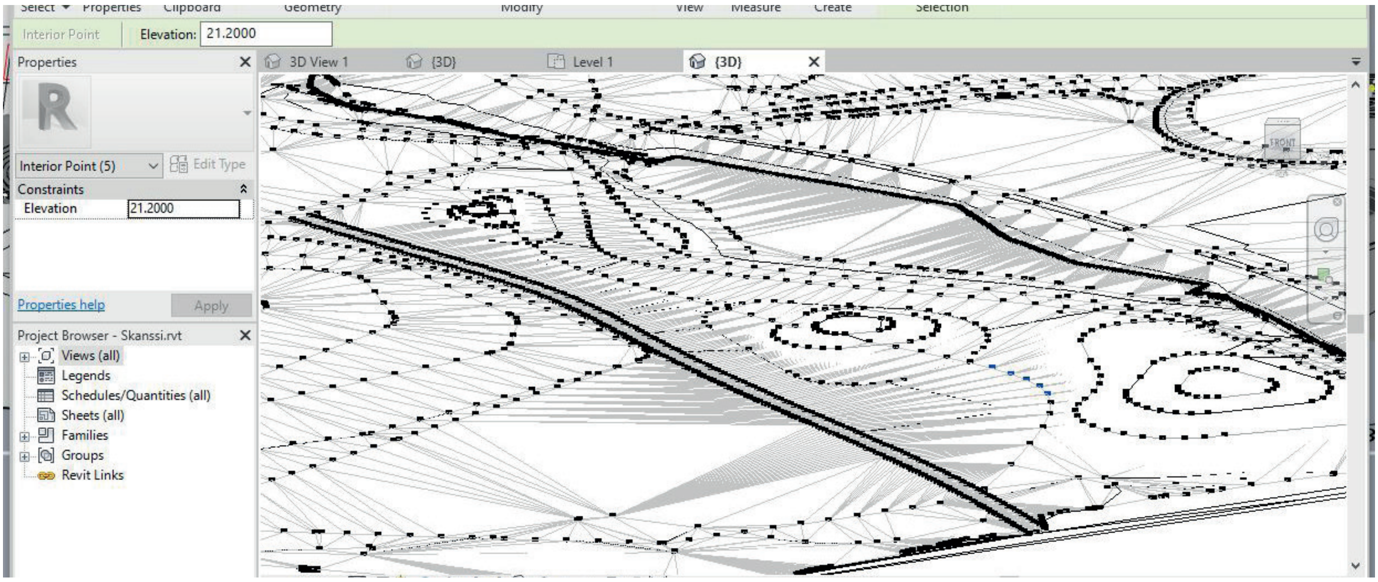
If the “coverage area” tool is used (page 62), it will automatically transform the existing terrain. However, it is not possible to have multiple overlapping terrains in Infraworks. [1] Therefore it is not possible merge two terrains into each other. Only terrains side-by-side can be visually connected.

Revit:

Each separate piece of terrain needs to be separated into its own DWG file. The separate pieces can then be made into toposurfaces in Revit and then combined.

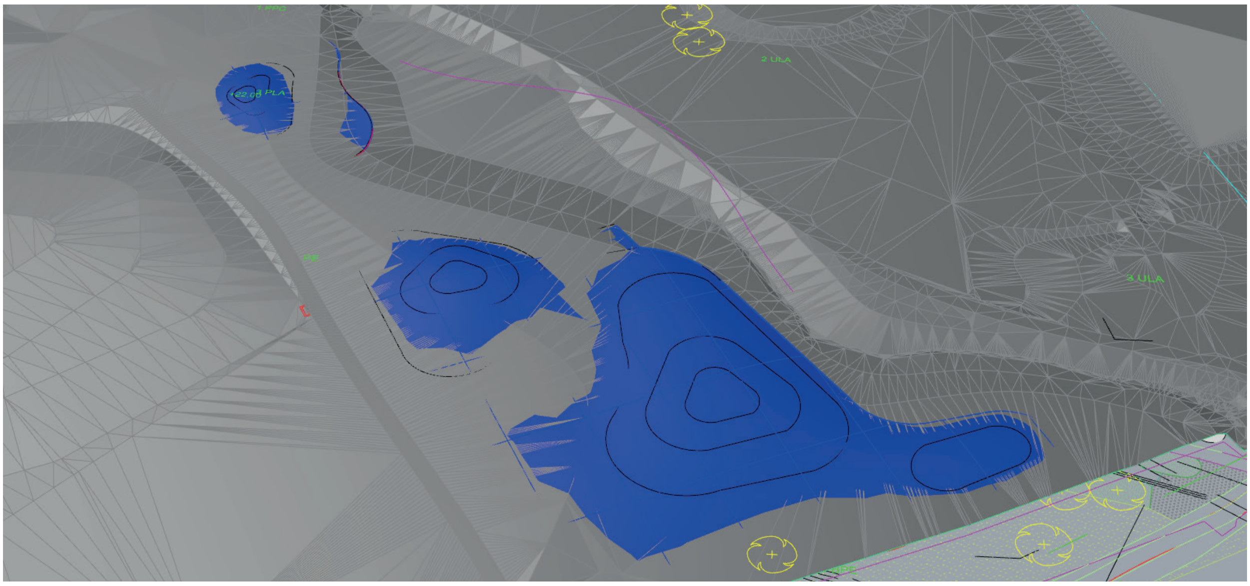


The overlapping surfaces can be merged with one click. However, the result would be better with some manual adjustments before merging. It is best to adjust the contours rather than the 3D model, because modifying the toposurface in Revit means vertex-by-vertex adjustments.



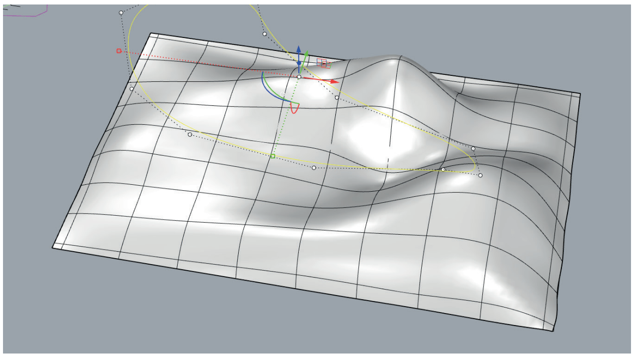
1 Knowledge.autodesk.com. (no date). To Set the Display Order of Multiple Terrain Surface Layers. https://knowledge.autodesk.com/support/infraworks/learn-explore/caas/CloudHelp/cloudhelp/2016/ENU/3PP-INF360-FUND-ASCENT/files/GUID-0143BFB8-E968-4DAC-BBAD-505182F196A2-htm.html Accessed 28.7.2019.

Rhino 3D:

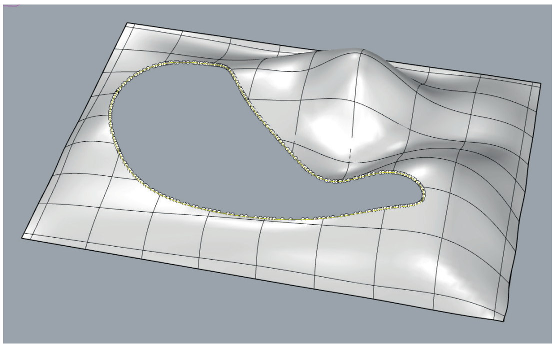


Above is shown Sweco's mesh overlapping with the designed NURBS patch surface.

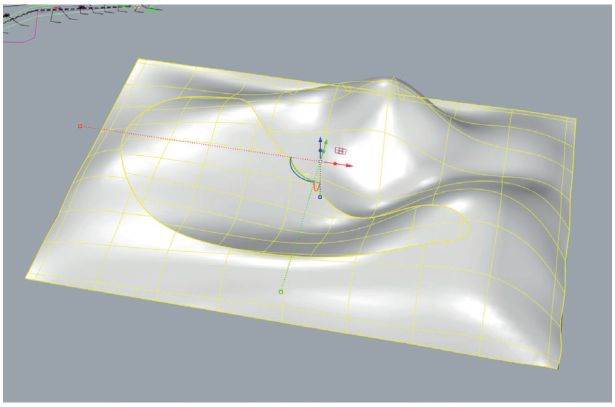
There is no way to merge a mesh with NURBS in Rhino. As the MeshtoNURB command in Rhino does not always work, [1] a Grasshopper script may have to be used to do the conversion from mesh to NURBS before attempting to connect the surfaces. Even using a script, the conversion is not always successful. As the focus of this study is not scripting, two other NURBS patch surfaces were used to test the merging process.



The edge can be projected onto the NURBS surface.



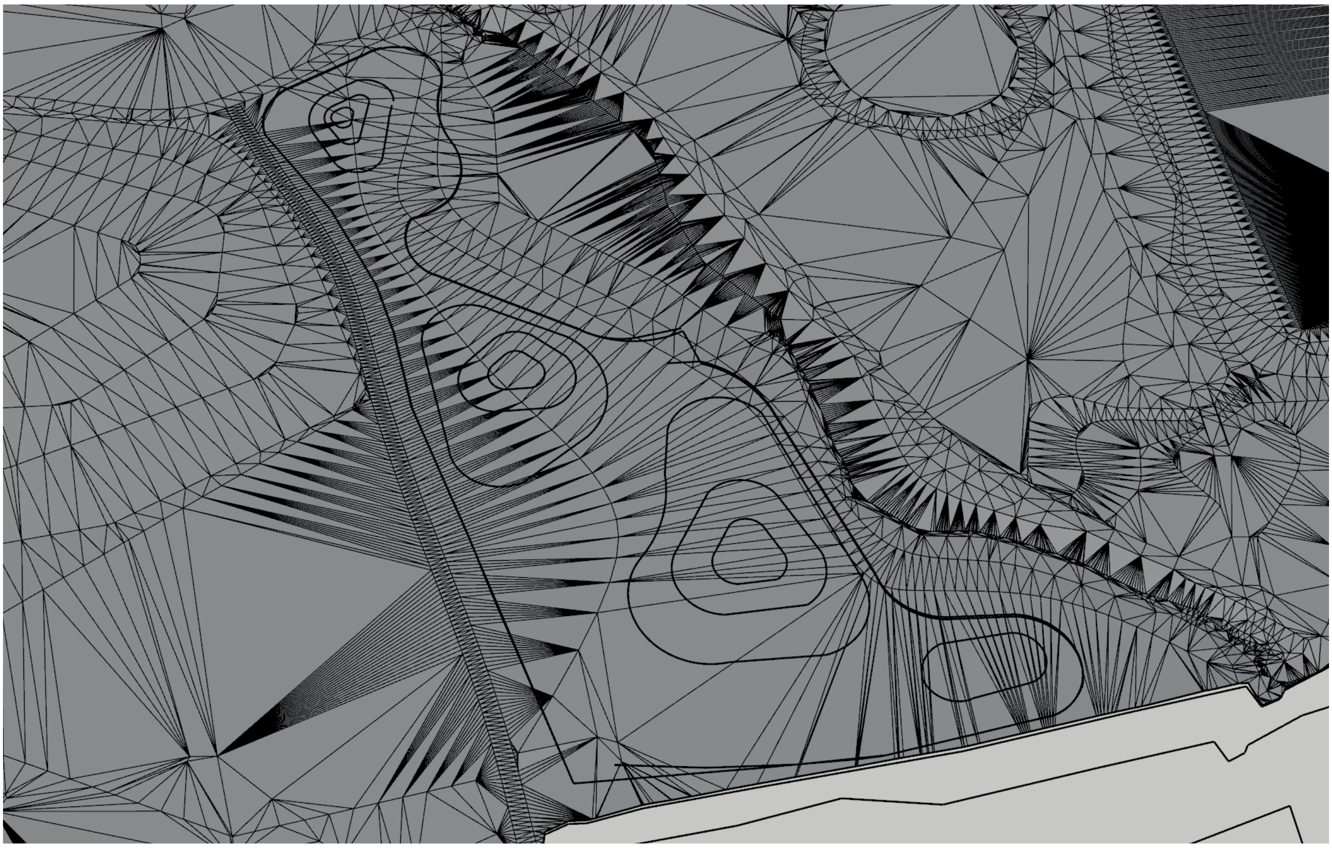
Created hole with Trim.



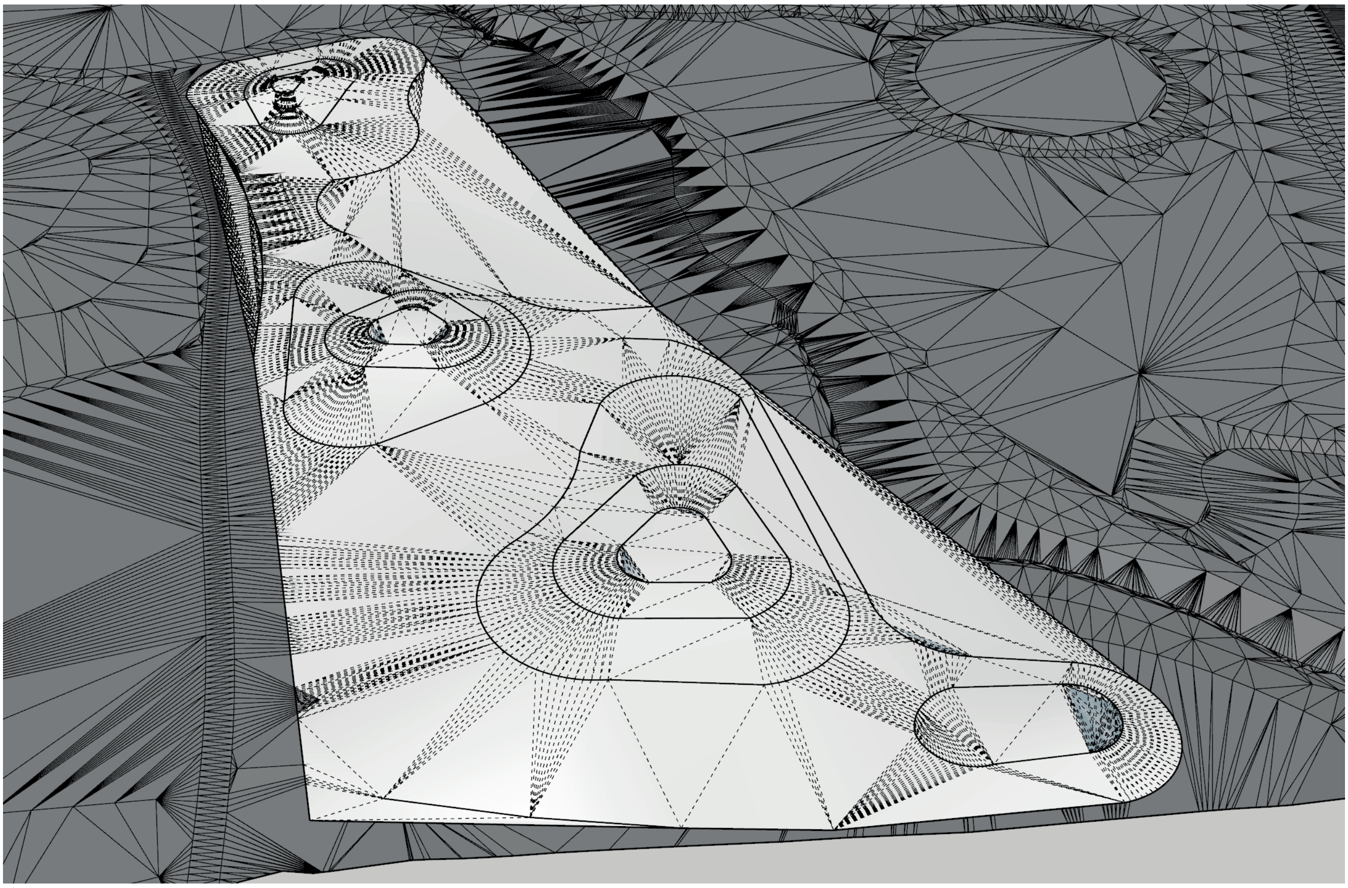
The two patches merged by using BlendSrf and Join. Note that complex edges can cause difficulties in succesfully using BlendSrf - selecting complex edges requires manual work, although chaining edges can ease this task somewhat.

1 Wiki.mcneel.com. (no date). The MeshToNurb Command. https://wiki.mcneel.com/rhino/meshtonurb Accessed 28.7.2019.

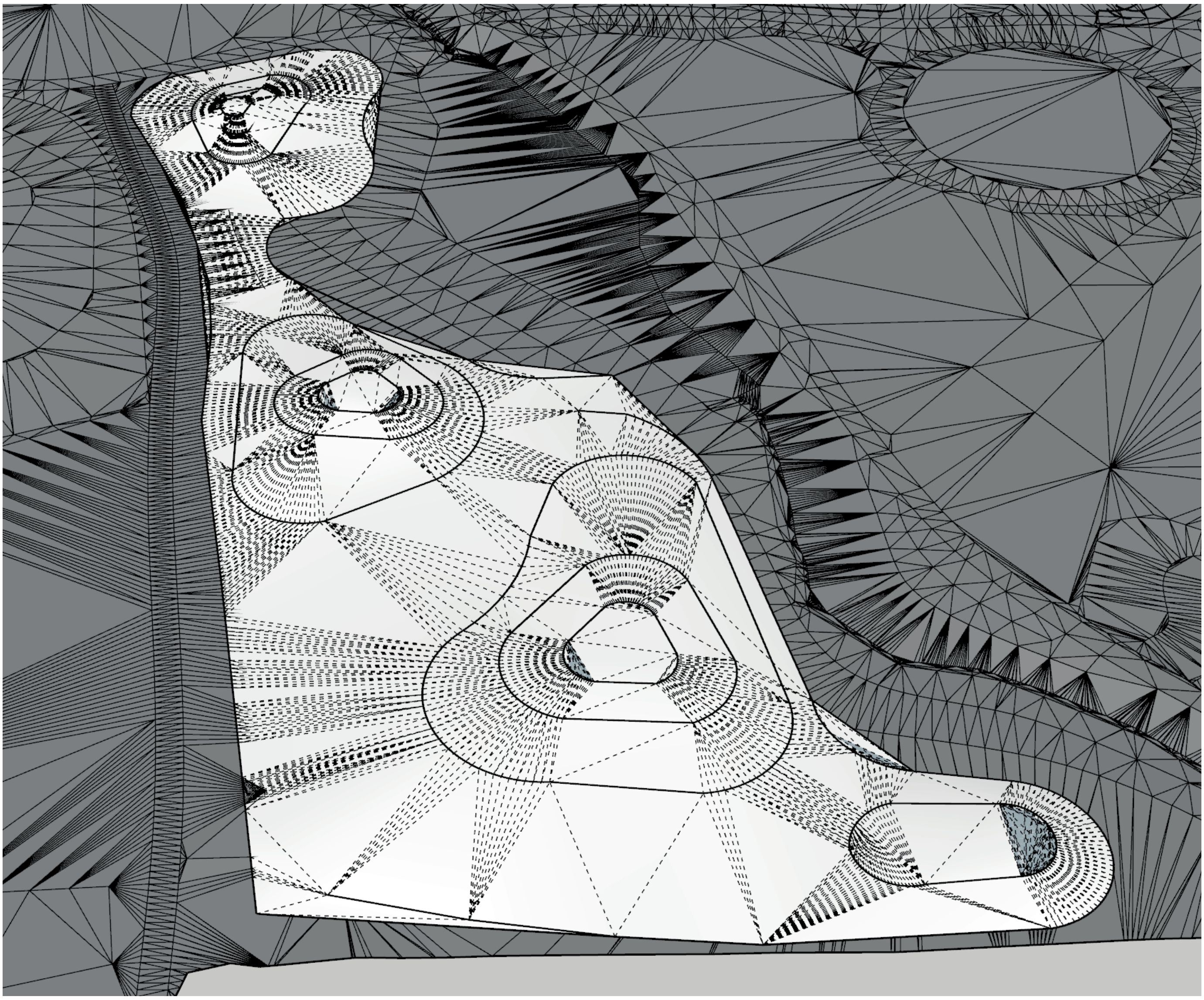
Sketchup:



One edge line was draped (projected) onto the TIN surface, then a new TIN surface was created.



Trimming the edges requires manual work.



After trimming, the edges would have to be connected manually to the existing surface. Connecting the two TIN surfaces would require an extensive amount of manual work, and will not be attempted.

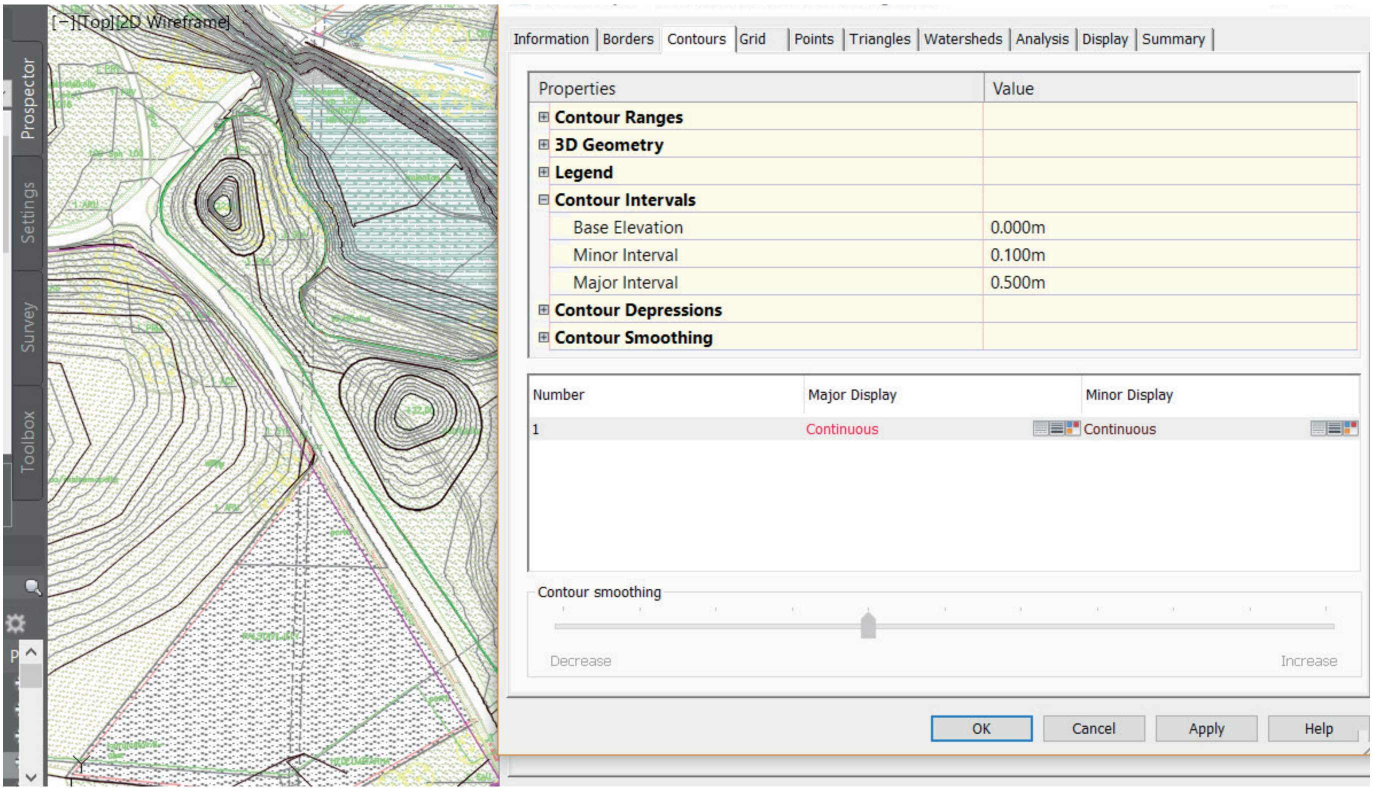
2.2. Verdicts

2. Landforms	Civil 3D	Infraworks	Revit	Rhino 3D	Sketchup Pro
2.2. Connecting to the existing terrain	Can connect surfaces that do not meet at egdes. Projecting edges of surface onto existing terrain before merging is not necessary, but recommended for a smoother transition.	No. Note that using the Coverage tool automatically shapes the current terrain.	Can connect surfaces that do not meet at edges. It is best to modify the contours rather than 3D model for a smoother transition. In cases when contours cannot be modified, the terrain has to be modified vertex-by-vertex.	No way to merge NURBS surface with mesh. Grashopper must be used to convert mesh to NURBS. Two NURBS surfaces can be joined, but two NURBS patches will be difficult because of the edges not meeting.	Can project edge line onto surface with Drape tool. Excess faces can be trimmed, but manually. Connecting TIN surfaces into one would require an unnecessary amount of manual work with large surfaces.

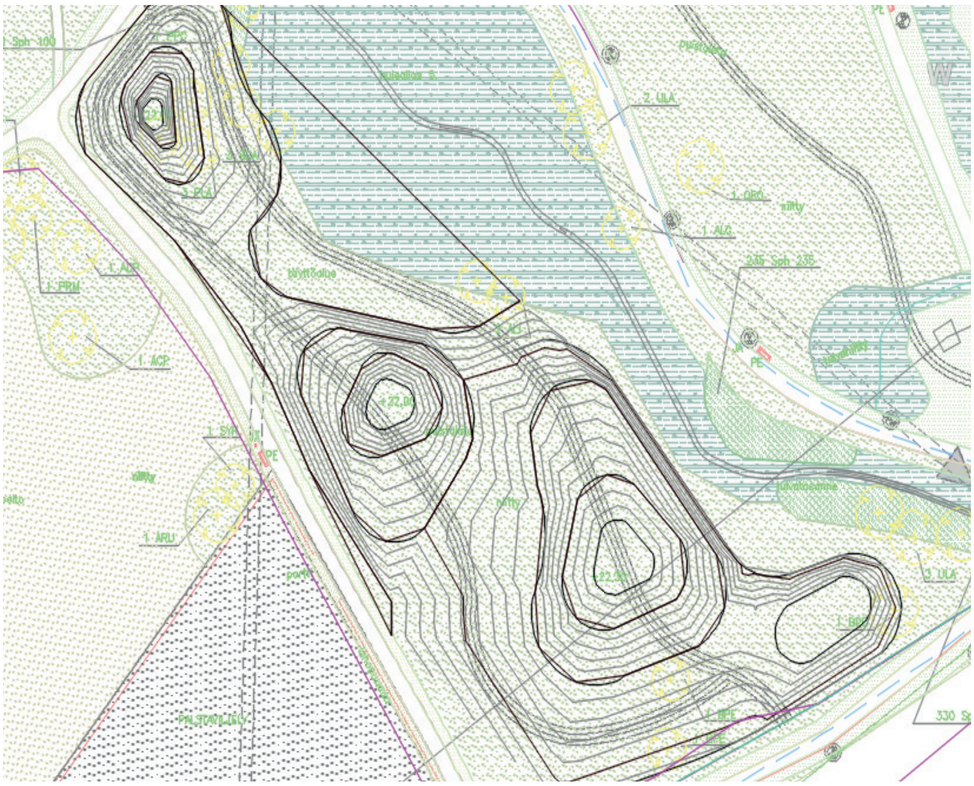
2.3. Resulting contours

The resulting contours are wanted in 10 cm intervals in DWG form. The contours are used in the site plan and can also be used to evaluate how accurately the software has modeled the designed landforms when compared against original designed contours.

Civil 3D:



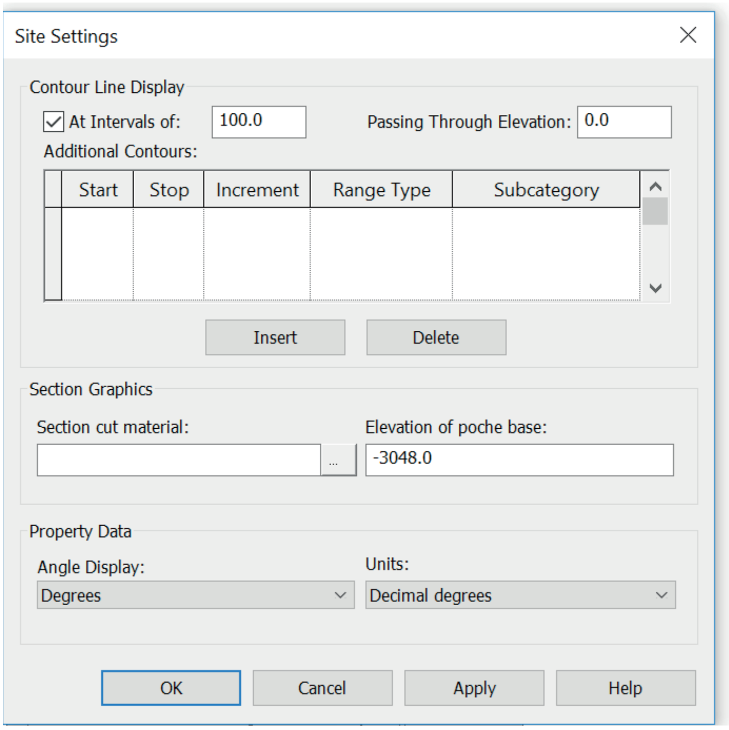
The contours can be set to be visible at wanted intervals from surface styles, as shown above. After this the surface can be exploded and the contours can be obtained. The resulting contours have height values. Resulting contours are shown in the image to the right.



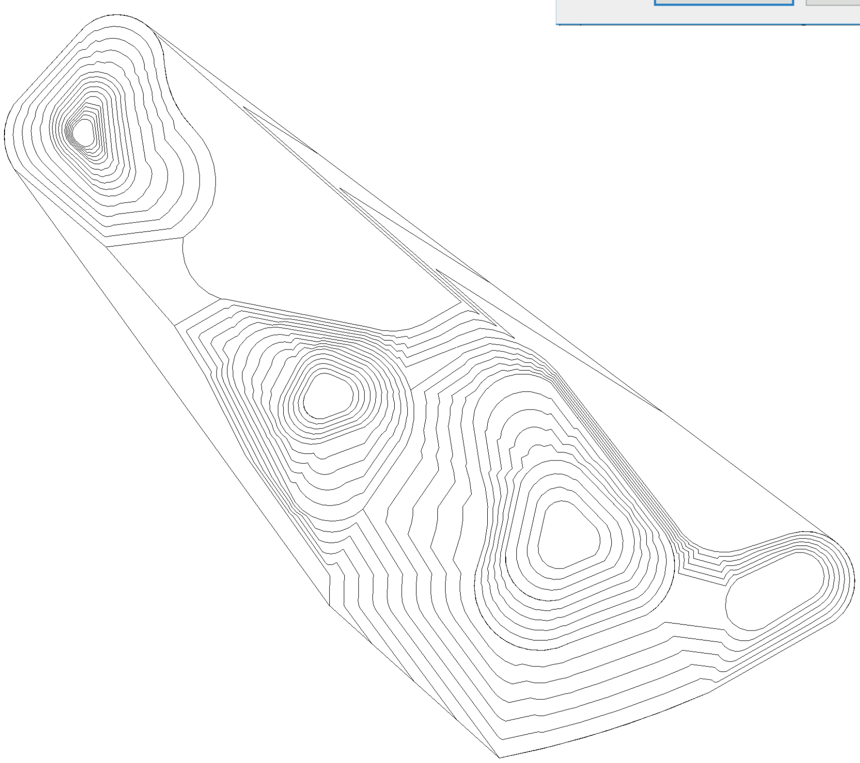
Infraworks:

Cannot export contours from surface.[1]

Revit:



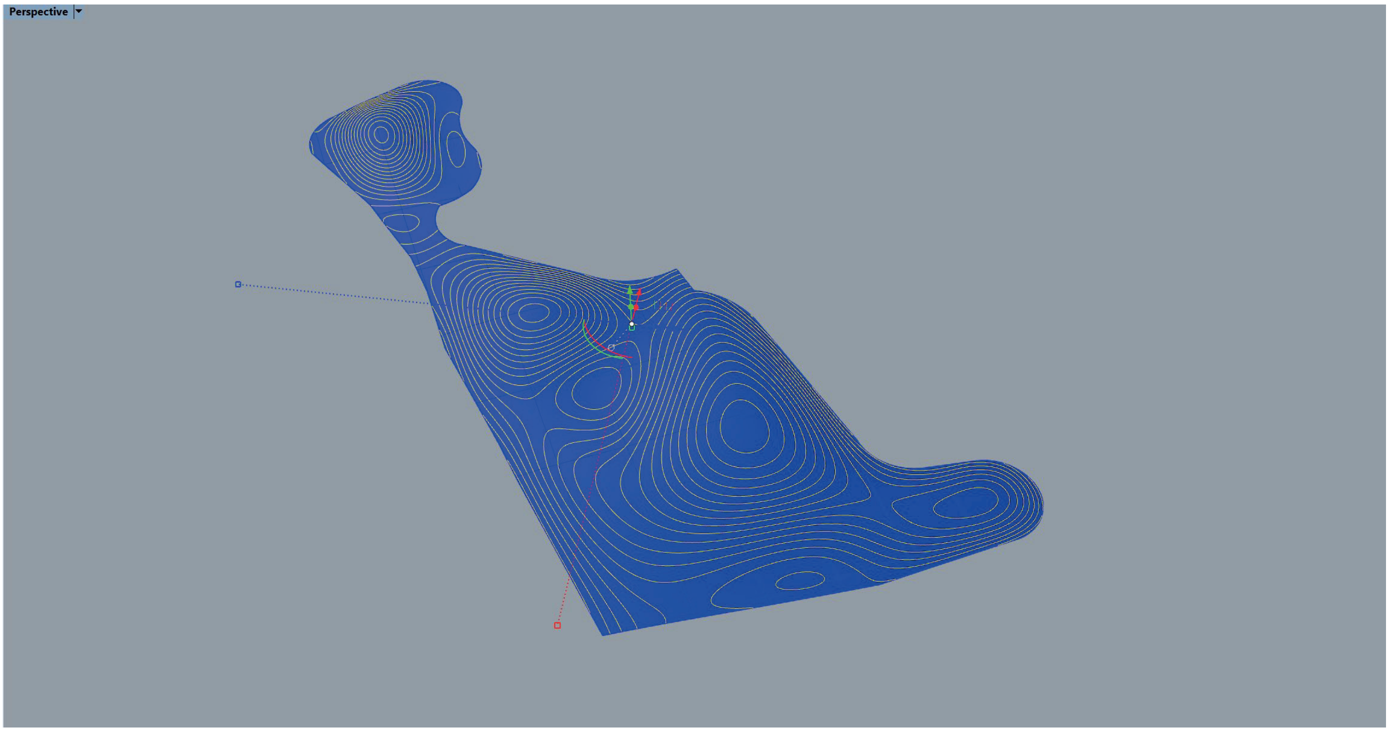
The wanted contour intervals can be set in "Site Settings", as shown to the right. After this the contours can be exported by changing to plan view and exporting to DWG. However, the exported contour lines will not have height values.



1 Knowledge.autodesk.com. (no date). About exporting model data. http://help.autodesk.com/view/INFM-DR/2015/ENU/?guid=GUID-2195722A-37BD-4054-A7B2-FF7C24BD08B7 Accessed 4.8.2019

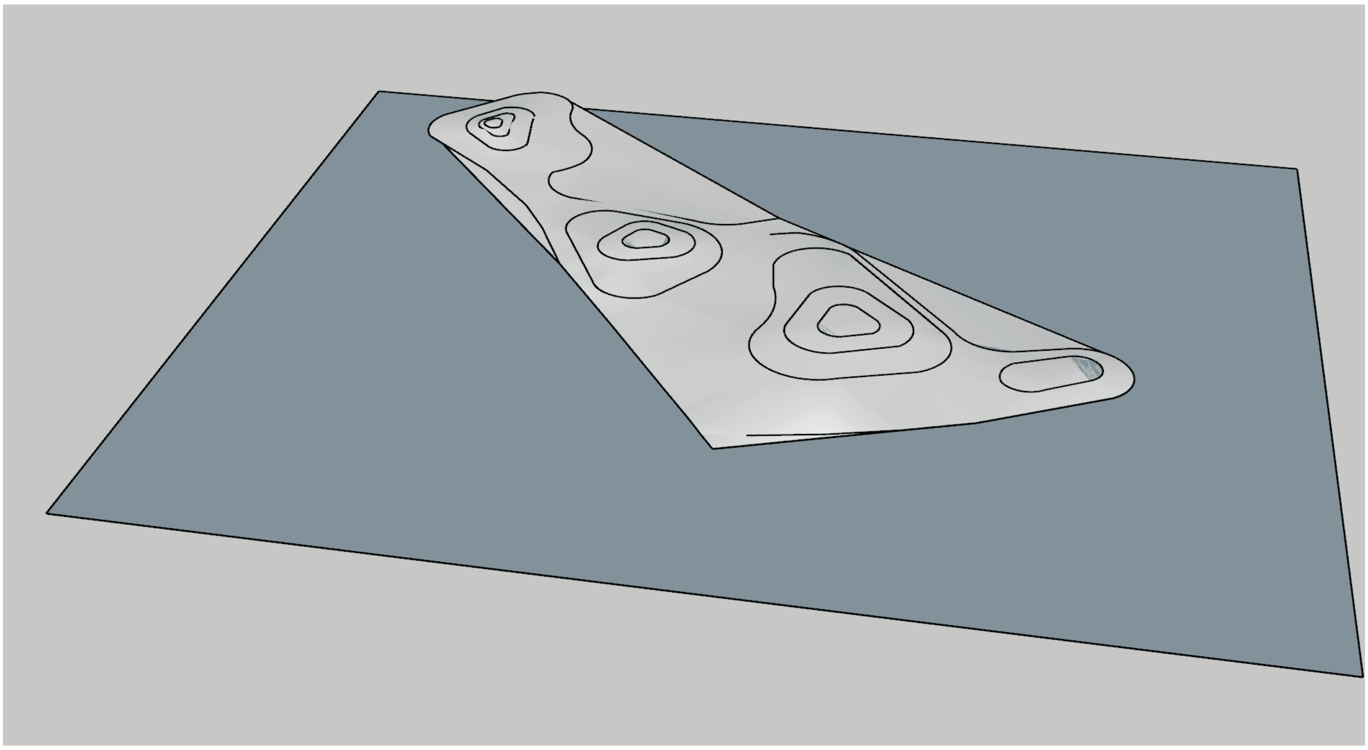
Rhino 3D:

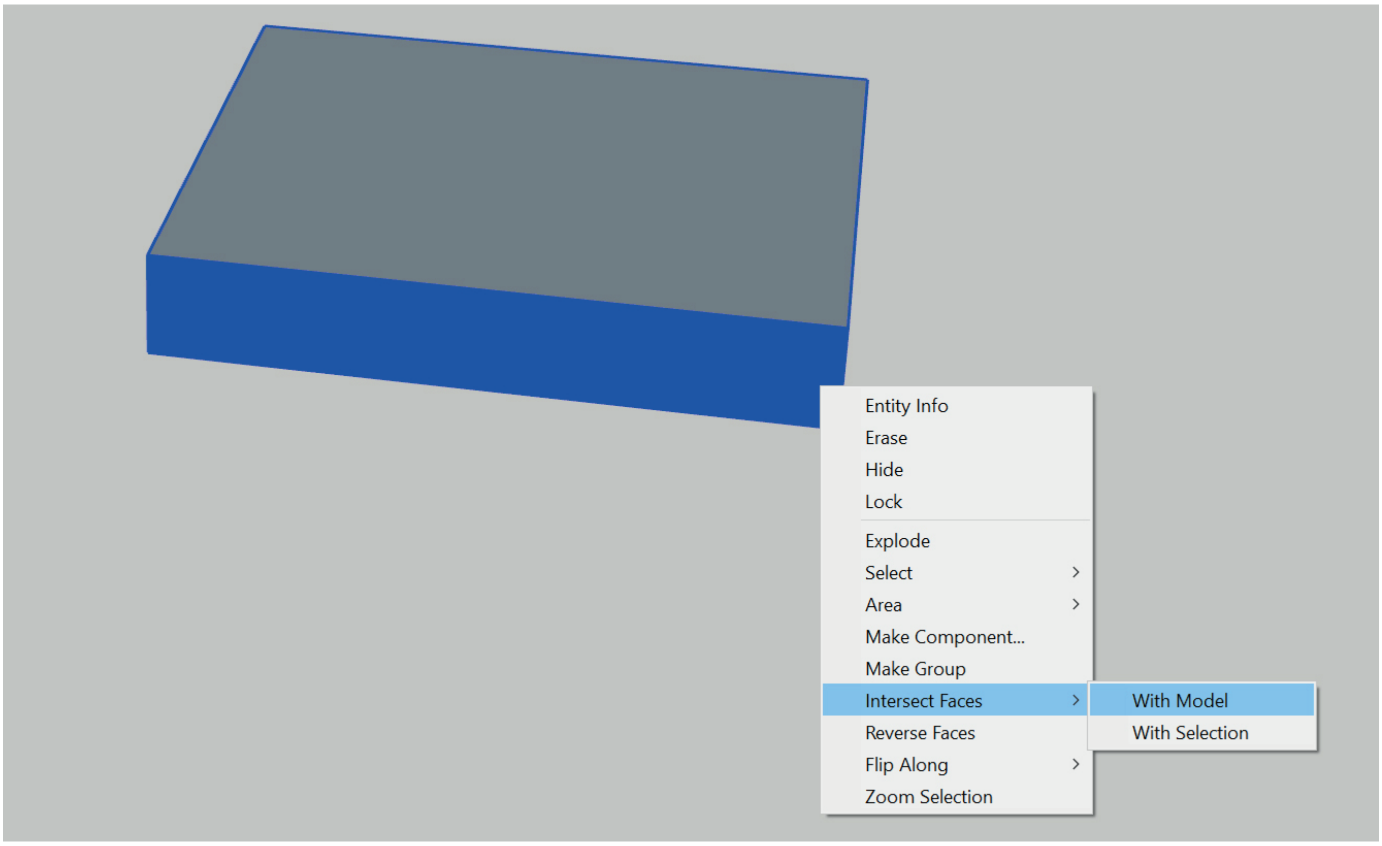
Rhino has a separate Contour command for creating contours. These contours can be saved in dwg format and include height information when exported. When compared to other software, the contours will be very smooth due to the NURBS surface that is used. However, surfaces made with the Patch command may include unintended mounds or hills.



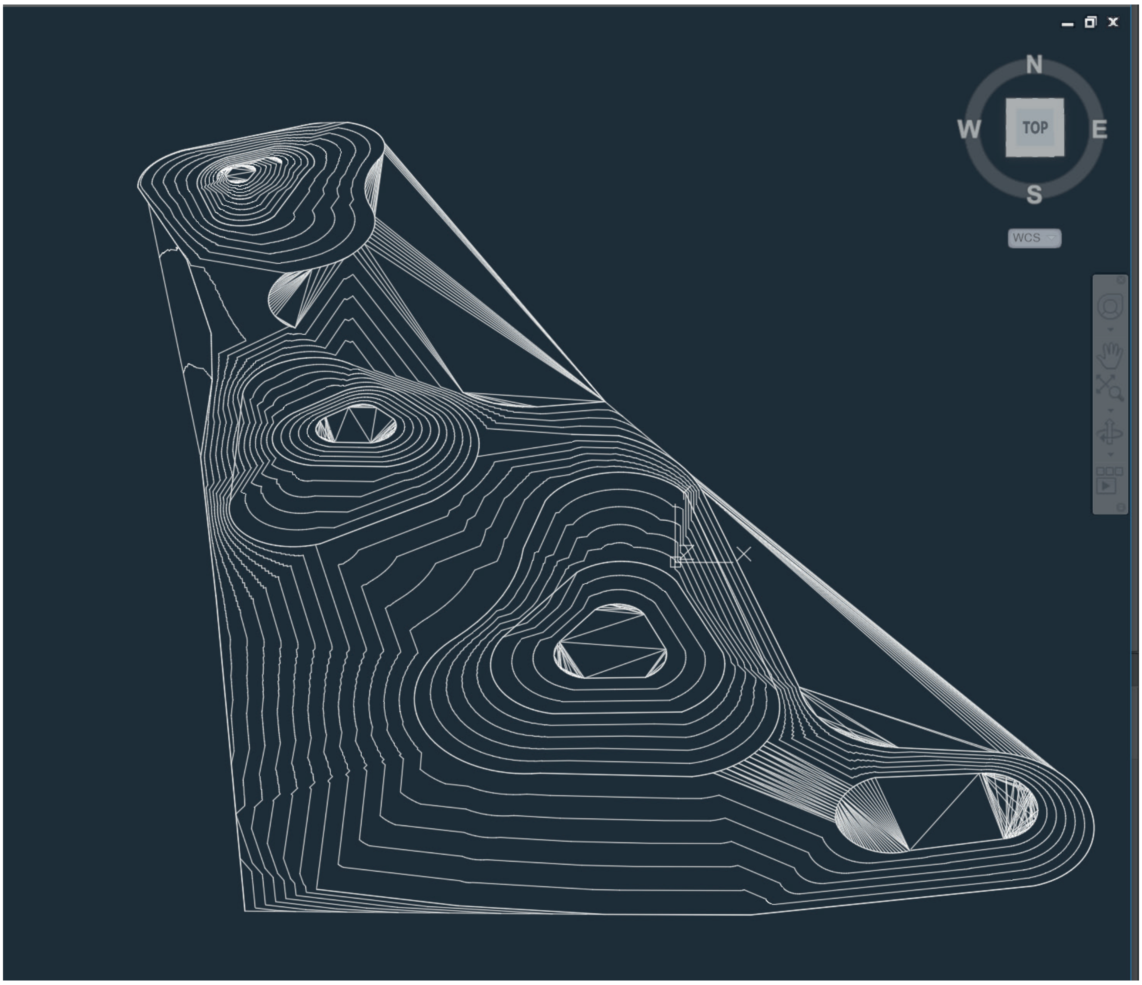
Sketchup:

Creating contours does not have a separate tool in Sketchup, but they can be created by drawing a plane and copying this plane at the wanted contour intervals, and then intersecting the contour planes with the terrain model.





The created contours include some unwanted triangulation lines. The contours can be exported into DWG in Sketchup Pro - however, it must be ensured that the model is in top-down view before exporting. Otherwise the file will be exported as flat 2D lines viewed directly from the perspective that the window is in, as shown below.



Unfortunately height values will not be included in the exported CAD contours - the contours will lay flat on 0-level.

2.3. Verdicts

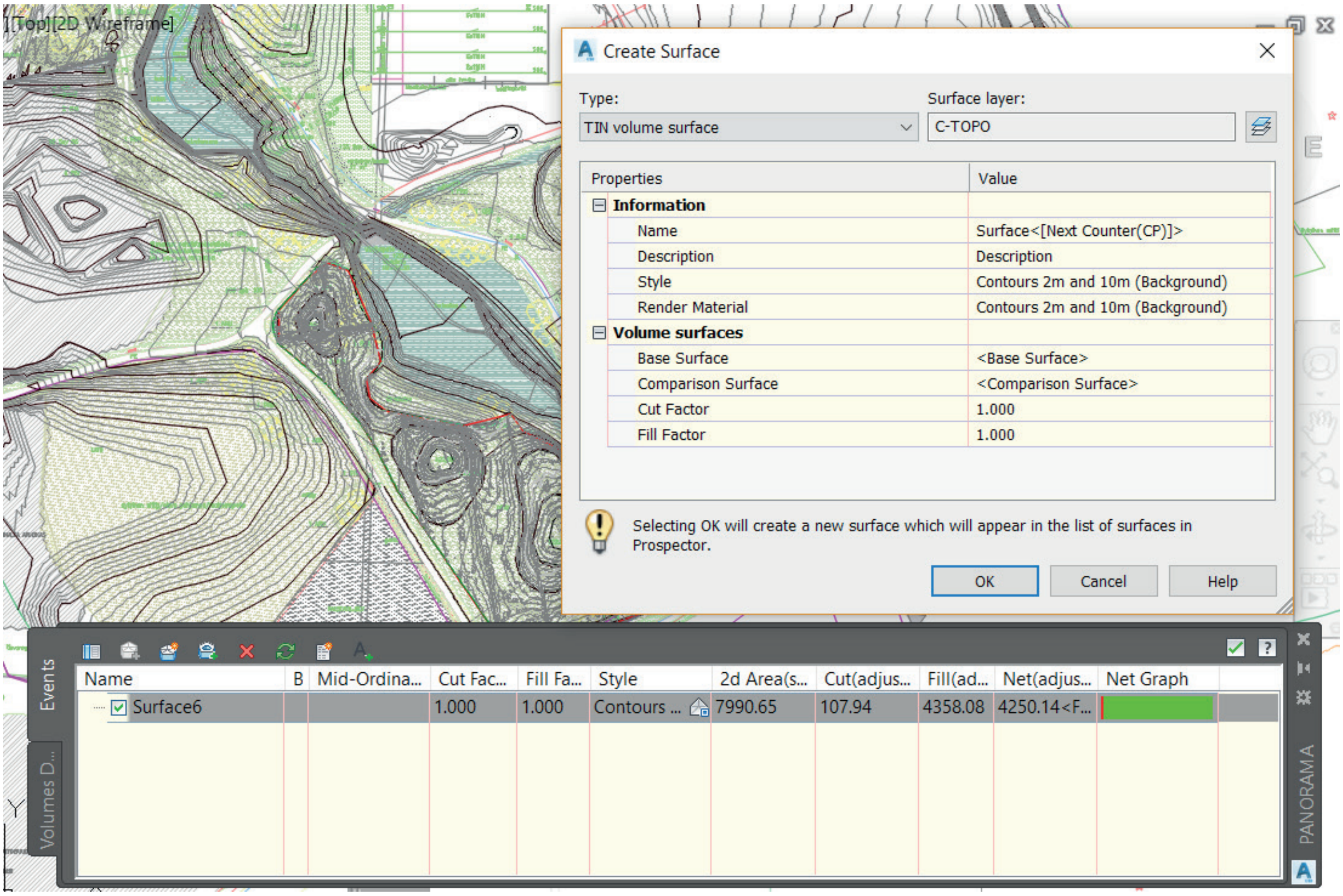
2. Landforms	**Civil 3D**	**Infraworks**	**Revit**	**Rhino 3D**	**Sketchup Pro**
2.3. Resulting contours from surface • format and height values • accuracy	Yes. Is already in dwg format. Exported contours have height values. Accuracy: Contours are jagged when created from a mesh. No unintenional lines or deviations from landform.	No.	Yes. Can be saved in dwg format in ground plan view. However, the exported contours do not have heights. Accuracy: Contours are jagged when created from a mesh. No unintenional lines or deviations from landform.	Yes. Can be saved in dwg format. Exported contours have height values. (5 pts) Accuracy: Contours are very smooth when created from NURBS. Contours can include unintentional mounds or hills.	Yes. Can be saved in dwg format in ground plan view. However, the exported contours do not have heights. Accuracy: Contours are jagged when created from a mesh. Includes some unwanted triangulation lines.

2.4. Calculating the volume

Calculating the volume of the fill is required for estimation of required landmass in construction. The designed surface is compared against the existing terrain exported from MML.

Civil 3D:

Civil 3D has a built-in feature for volume calculation. It requires only inputting the designed surface and the existing surface. Then the fill and cut volumes will be automatically calculated, as shown below.



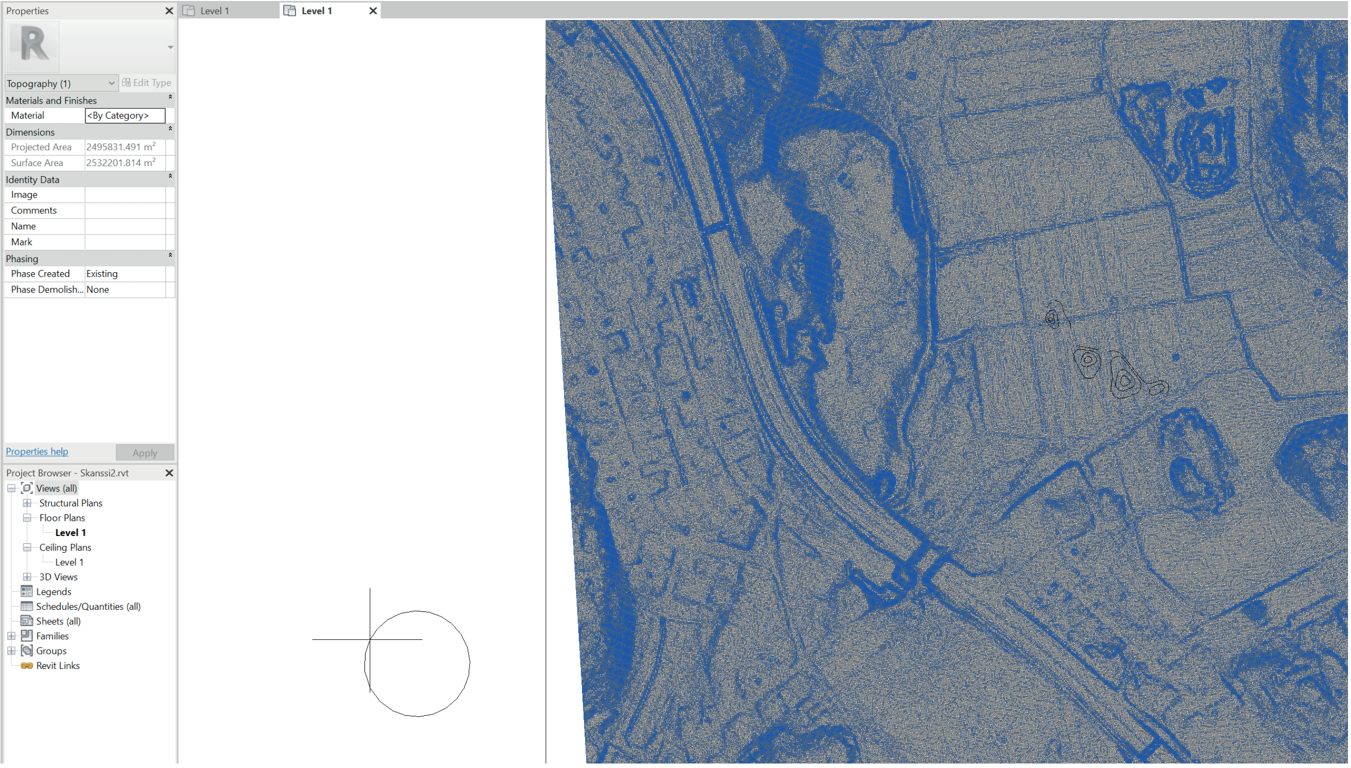
Fill: 4250m3

Infraworks:

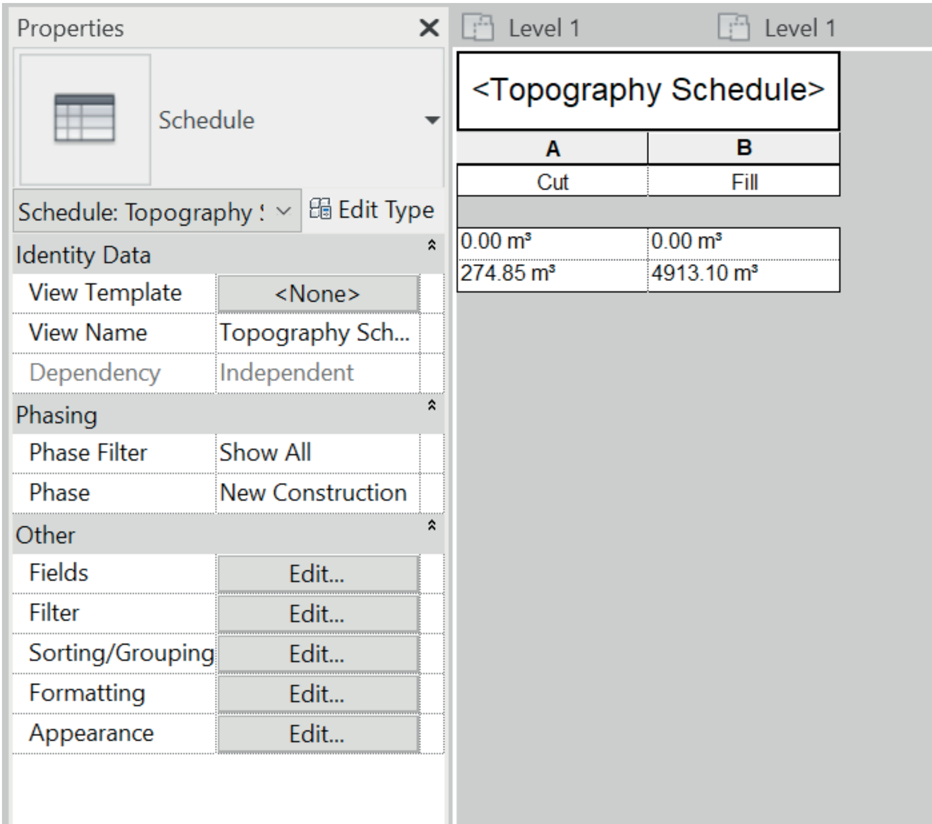
The volume of a “Coverage area” (page 62) can be calculated. [1]

1 Knowledge.autodesk.com. (no date). To measure terrain area and volume. https://knowledge.autodesk.com/support/infraworks/learn-explore/caas/CloudHelp/cloudhelp/ENU/InfraWorks-UserHelp/files/GUID-27C4105B-983B-44A8-BDBC-2C0D09F8CDF7-htm.html Accessed 28.7.2019.

Revit:



Can be done with scheduled phases. The existing terrain has to be moved to “Existing Phase”, as shown above, and the designed terrain to “New Construction Phase”. The volume will be shown in the topography schedule, as shown beside. [1]

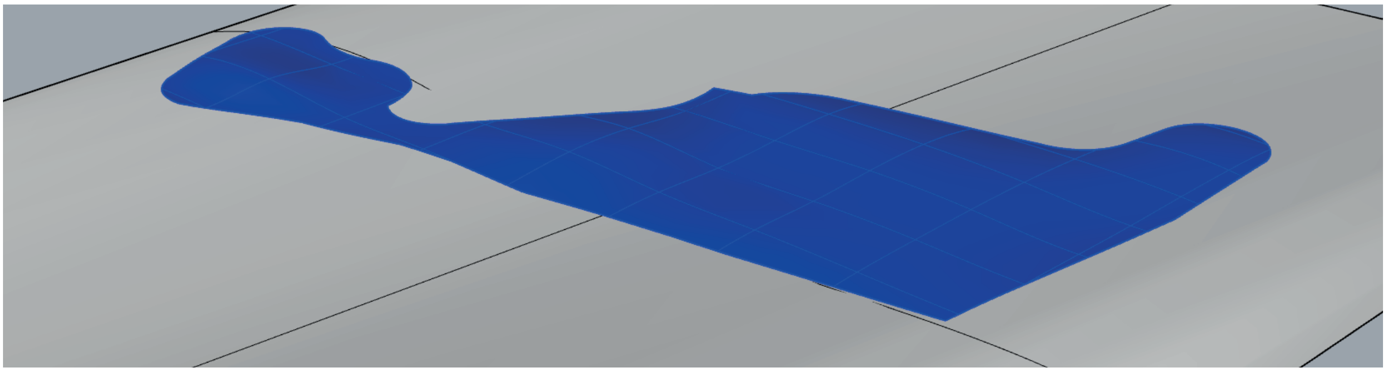


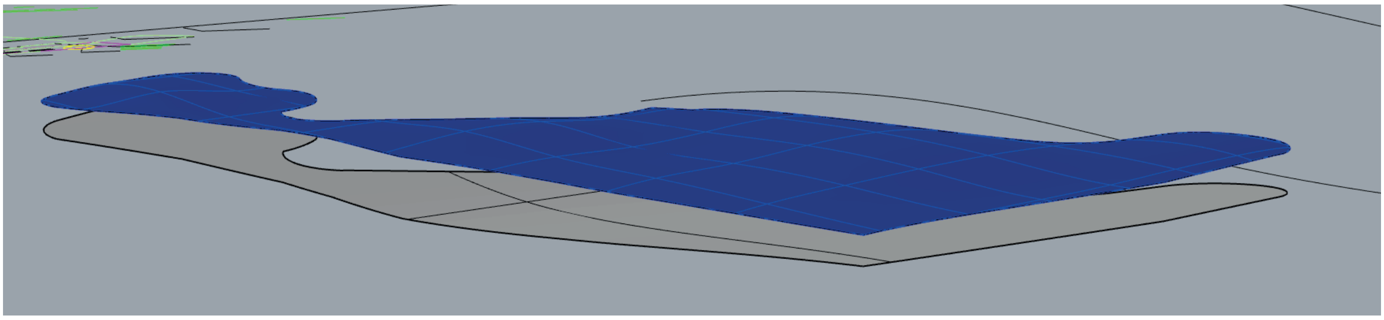
1 Knowledge.autodesk.com. (no date). About Reporting Cut and Fill Volumes on a Site. https://knowledge.autodesk.com/support/revit-products/learn-explore/caas/CloudHelp/cloudhelp/2016/ENU/Revit-Model/files/GUID-F9994BBC-027A-41B8-8852-FB33A34C3AC7-htm.html Accessed 28.7.2019

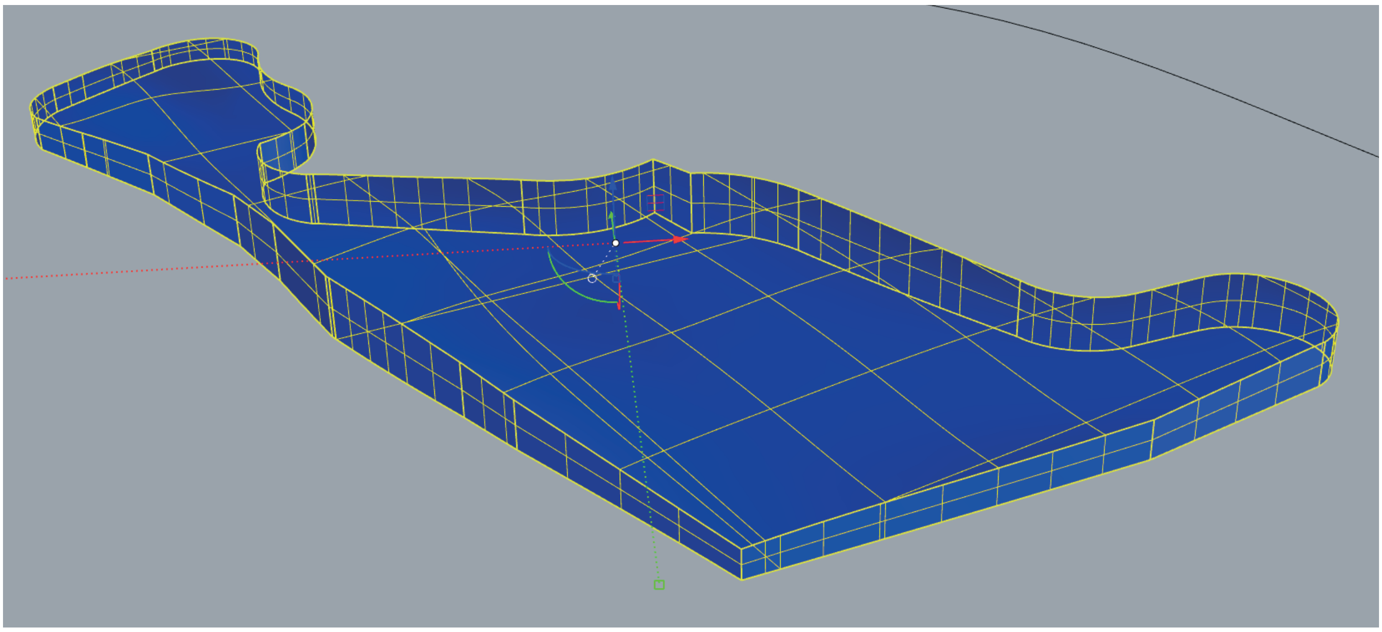
Rhino 3D:

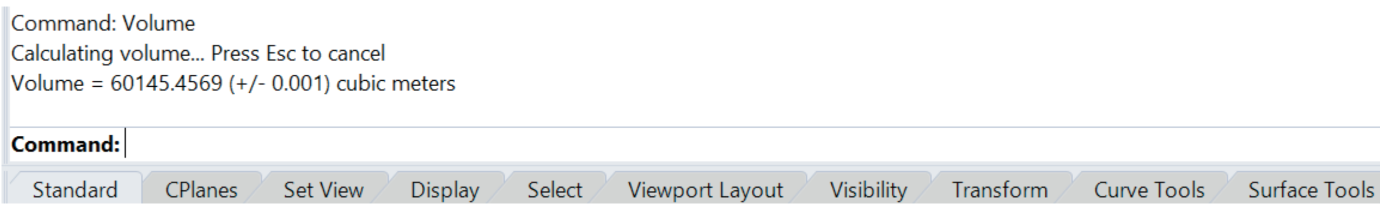
To save time on converting a mesh to NURBS, a test NURBS surface will be used to calculate the volume instead.

The volume calculation in this case can be done by duplicating the border of the designed surface, projecting it onto the existing surface, trimming it and creating a loft to connect the two surfaces, so that a solid is formed. Then the volume of that solid can be checked with the volume command.



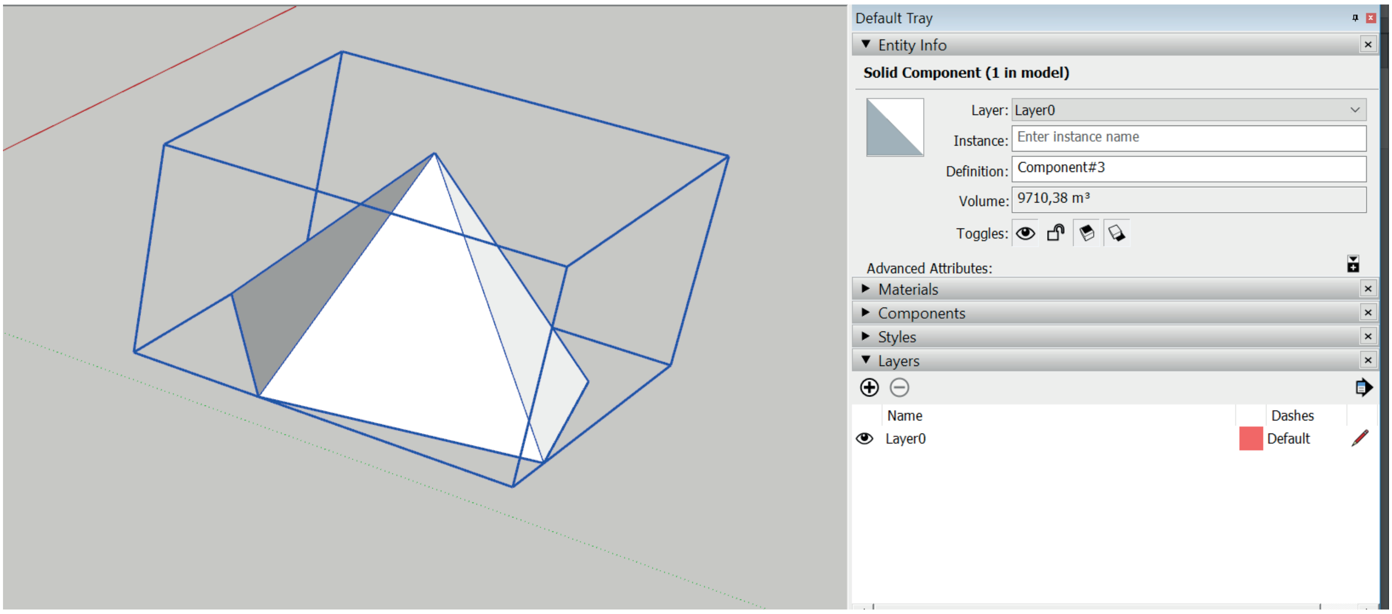




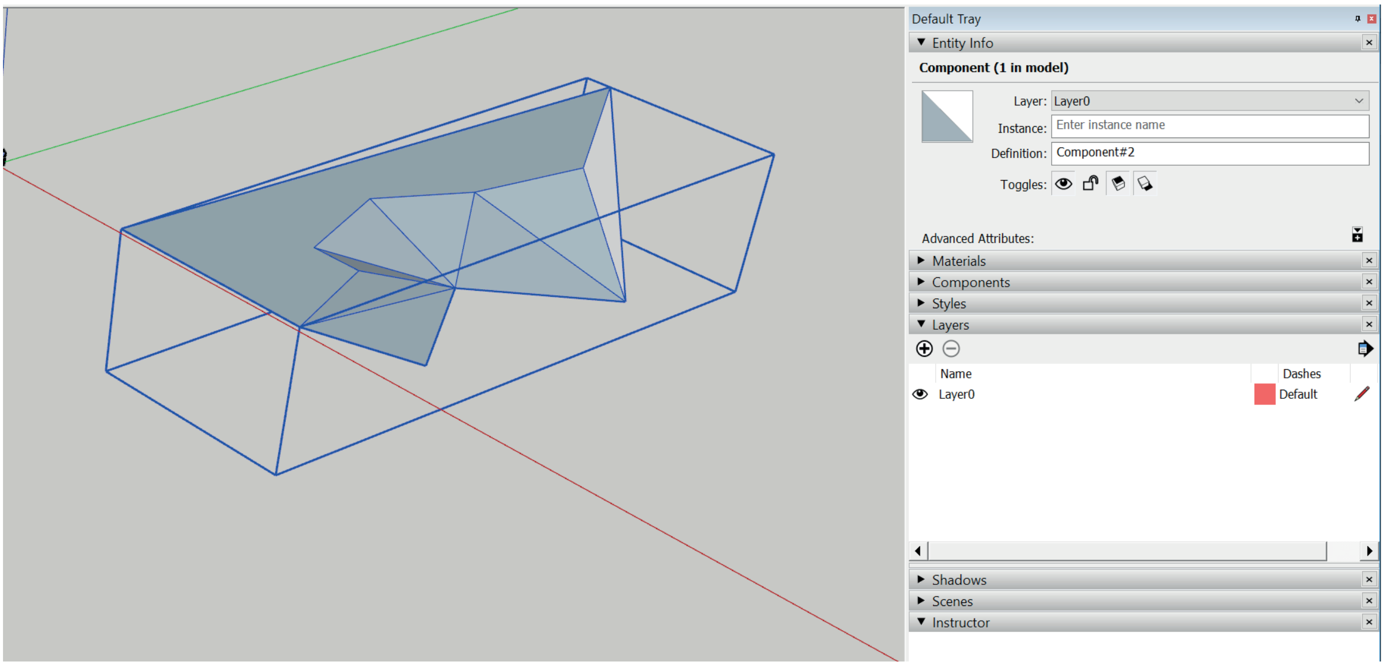


Sketchup:

It is possible to get the volume of a solid object in Sketchup by creating a component out of it, and checking the entity info.



However, as soon as the object gets slightly more complex, creating a solid may prove to be difficult. If the object is not a solid, the volume is not shown, as seen below in the properties panel.



2.4. Verdicts

2. Landforms	Civil 3D	Infraworks	Revit	Rhino 3D	Sketchup Pro
2.4. Calculating volume	Has a dedicated tool.	Can measure volume of Coverage areas made in Infraworks.	Has a dedicated tool.	Has a dedicated tool.	Theoretically possible, but would require a lot of manual work with large surfaces.

3.1. Water simulations

In this design, calculating waterflow was left to storm water management specialists. However, as the ground massing is next to a water area, it could be useful to eg. calculate the direction of the flow of water, and use this to inform the design of landforms as a landscape architect. Because it was not included in the design process, the presence of waterflow tools is evaluated using software manuals as source material.

Civil 3D:

Can create a watershed analysis and a water drop analysis for tracing the path that water would take across a surface. [1]

Infraworks:

Can analyse watershed areas. [2]
Can visualize rivers and lakes. [3]

Revit:

Cannot find on the manual or through a Google search anything on water simulations (other than plumbing systems).

Rhino 3D:

Cannot find on the manual or through a Google search anything on water simulations. Might be possible with Grasshopper or plug-ins.

A found Python script for calculating drainage directions with Grasshopper:
https://www.grasshopper3d.com/forum/topics/drainage-direction-script

Sketchup:

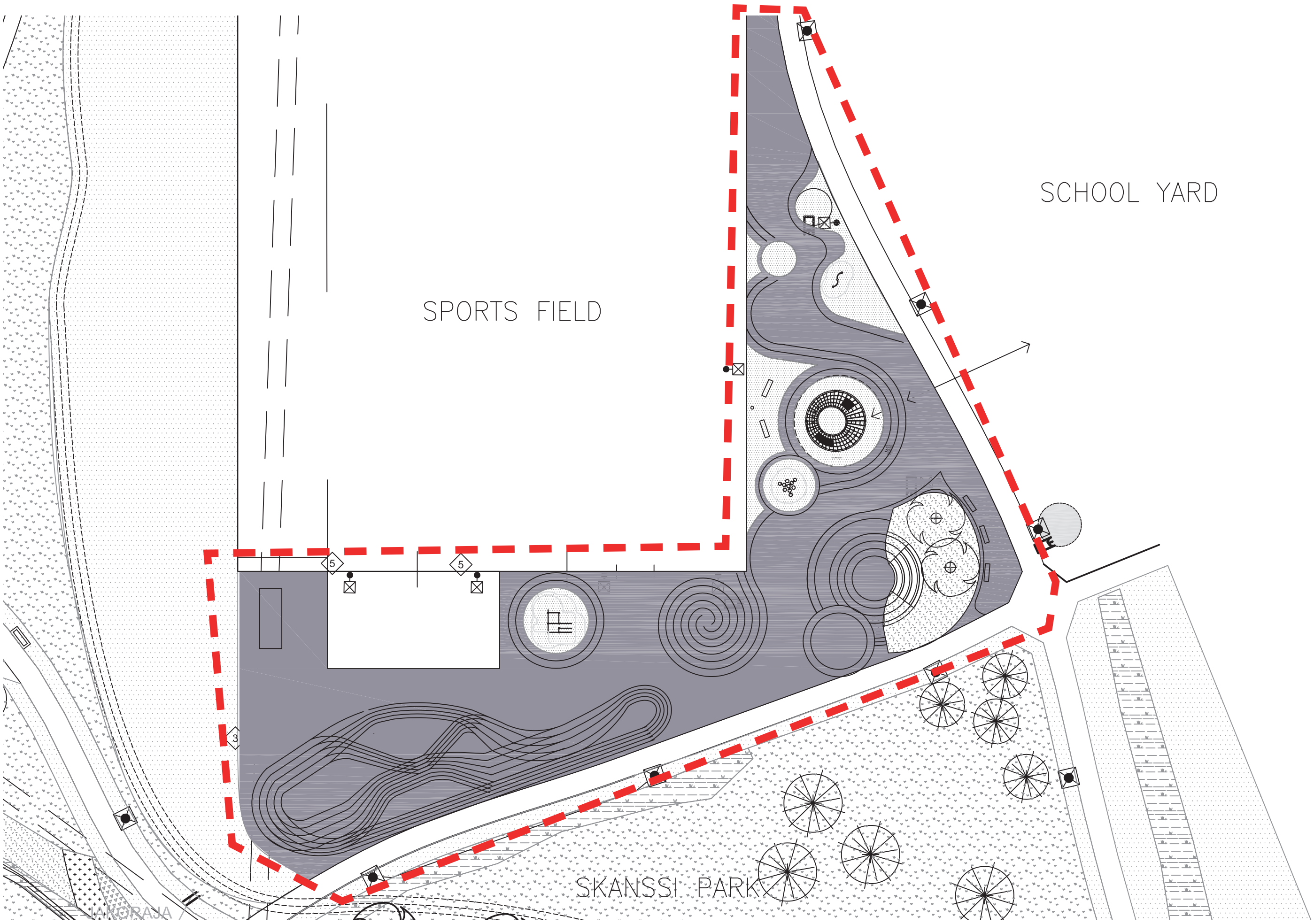
Cannot find on the manual or through a Google search anything on water simulations.

3.1. Verdicts

3. Other elements of landscape design	Civil 3D	Infraworks	Revit	Rhino 3D	Sketchup Pro
3.1. Water	Watershed and waterdrop analysis.	Watershed analysis. Visualization of still water and animated flow of water.	Visualization of still water.	Visualization of still water. Some analysis may be possible with scripting or plug-ins.	Visualization of still water.

1 Knowledge.autodesk.com. (no date).Tutorial: Creating a Watershed and Water Drop Analysis. https://knowledge.autodesk.com/support/civil-3d/getting-started/caas/CloudHelp/cloudhelp/2019/ENU/Civil3D-Tutorials/files/GUID-23EC67A6-0084-4DAC-B58F-141155DB7E29-htm.html Accessed 28.7.2019.
2 Knowledge.autodesk.com.(no date). About Watershed Analysis. https://knowledge.autodesk.com/support/infraworks/learn-explore/caas/CloudHelp/cloudhelp/ENU/InfraWorks-DrainageDesign/files/GUID-EEAFD756-4301-47EF-AB8B-9526B9AF3580-htm.html Accessed 28.7.2019.
3 Knowledge.autodesk.com. (no date). To add or modify water areas and rivers. https://knowledge.autodesk.com/support/infraworks/learn-explore/caas/CloudHelp/cloudhelp/ENU/InfraWorks-UserHelp/files/GUID-2EE48154-AEE2-4F13-ADC0-4CEF5B3C60F2-htm.html Accessed 28.7.2019.

5.2.2. Skanssi - Sports park



This design task is chosen to evaluate the 3D modeling of other elements of landscape design besides landforms (and waterflow). The set-up stage can be left out, since it was already done in the landmassing task. The sports park located in the Skanssi park was designed by author with the goal to place outdoor sports equipment suitable for high schoolers, and to fulfill the client's wishes regarding the form language.

A 3D model of the designed terrain is required for the combination model. Only the locations of sports equipment and vegetation are needed, however structures such as the amphitheater are represented with 3D geometry. Lighting plan and 3D models are provided by lighting designers. 3D models of the park paths are created by street designers and are embedded into the landscape 3D model. The 3D model is made based on the site plan designed by author, and sections are created using the 3D model.

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3. Other elements of landscape design
    3.2. Routes
    3.3. Structures (Amphitheater + terrain modification)
    3.4. Playground equipment / street furniture
    3.5. Vegetation
    3.6. Lighting
4. 2D drawings
    4.1. Site plan
    4.2. Section
5. Viewing the 3D model
    5.1. Perspective view
6. Compatibility
    6.1. FilE formats

3.2. Routes

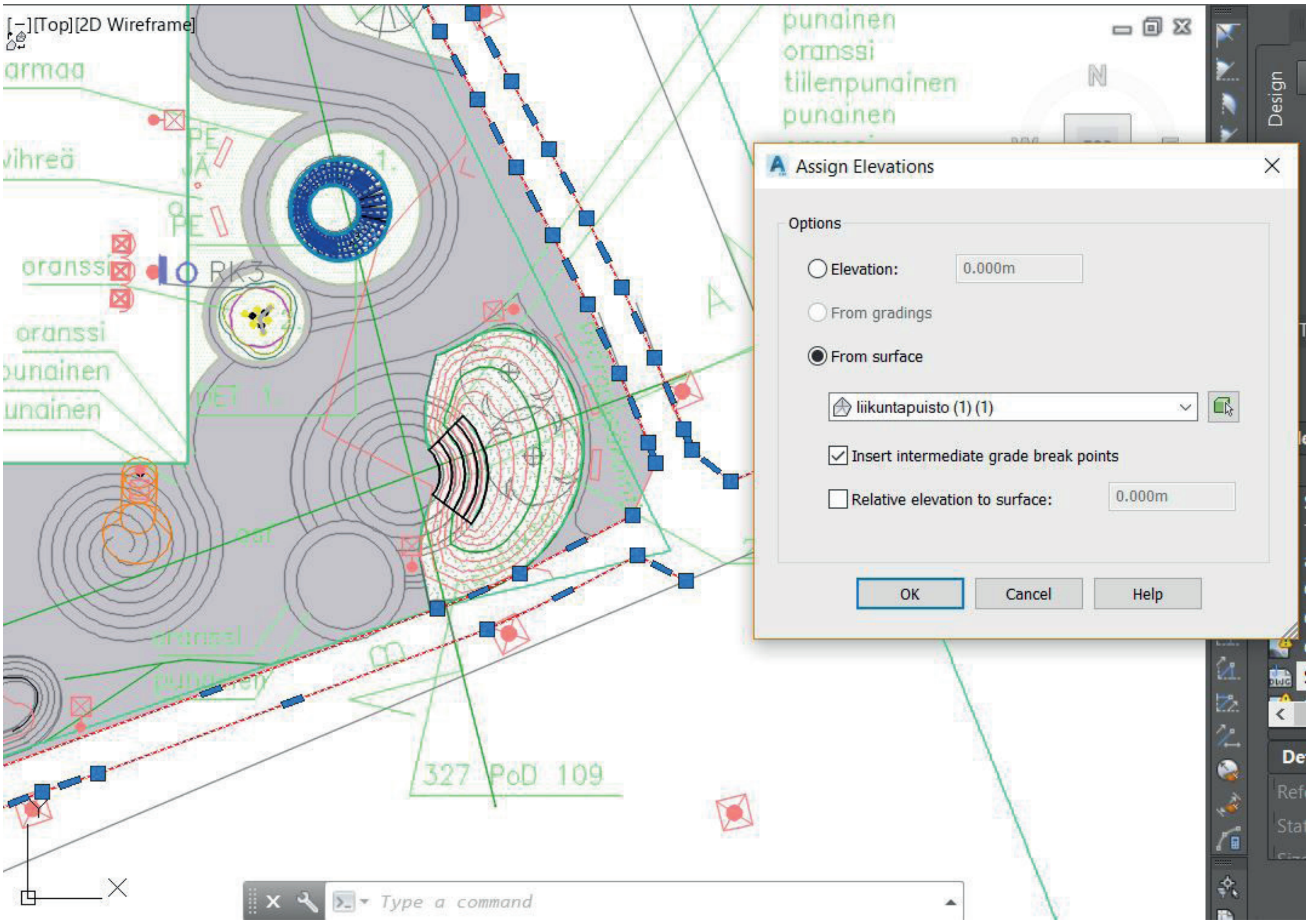
The most basic requirement for showing routes on the 3D model is being able to project the outlines of the paths onto the terrain, so that the location of the road can be seen visually. For visualization, it should also be possible to distinguish the road from the surroundings with a material or a color. In the construction phase, however, the paths should also have the correct slopes and relation to the terrain to allow for water drainage. In this project, that level of accuracy was left to road planners to design and model. This is why achieving the most basic level is focused on in this comparison instead. However, more complex road tools will be referred to when appropriate.

Civil 3D:

Civil 3D has specialized tools for designing roads. More info on road design in Civil 3D can be found here: https://knowledge.autodesk.com/support/civil-3d/learn-explore/caas/simplecontent/content/road-design-workflow-autocad-civil-3d.html

It is possible to create a separate surface for the road and add a material to it for visualization purposes.[1]

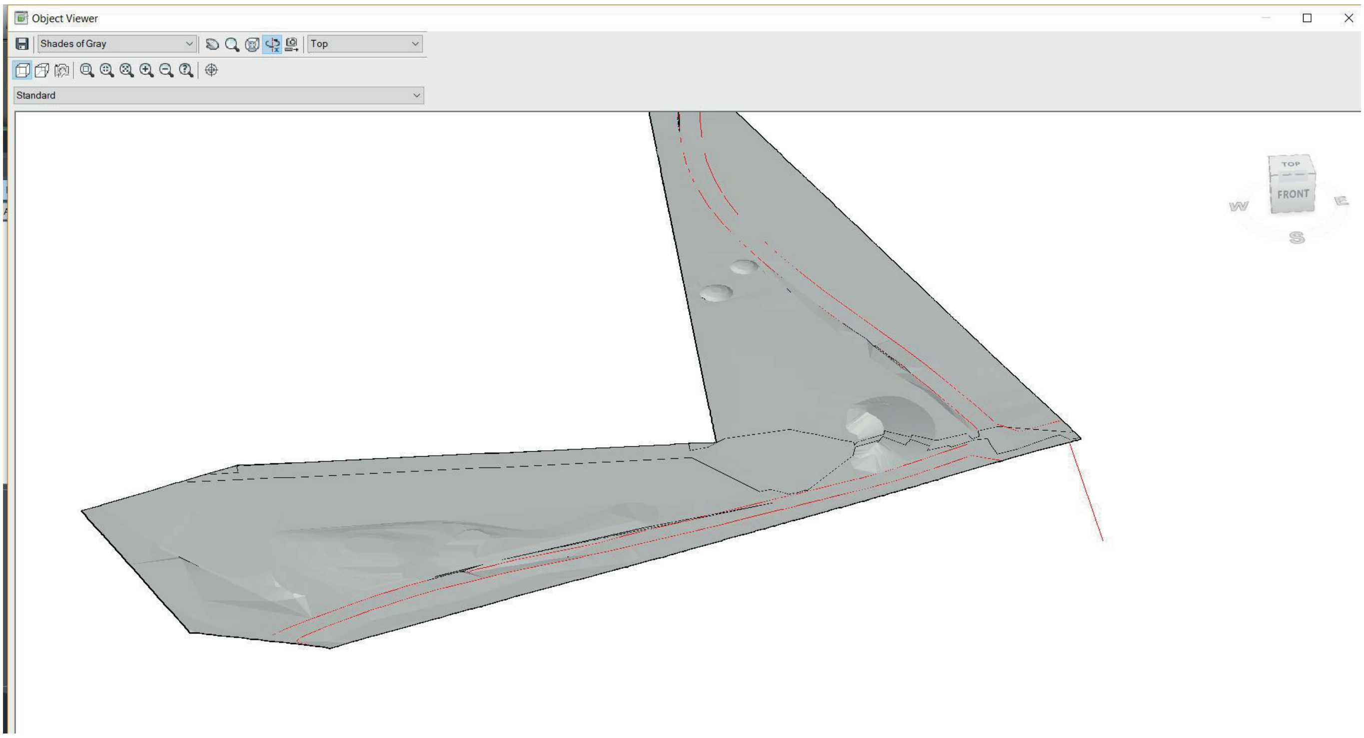
Outlines of paths can be projected on terrain by first converting the lines to feature lines, then assigning the elevations of the surface to the feature line. [2]



Elevation assignment of paths depicted above.

1 Knowledge.autodesk.com. (no date). To work with render materials. https://knowledge.autodesk.com/support/civil-3d/learn-explore/caas/CloudHelp/cloudhelp/2019/ENU/Civil3D-UserGuide/files/GUID-D85C2AF2-B4C1-4252-B6AC-BE765B2D77FE-htm.html Accessed 4.8.2019

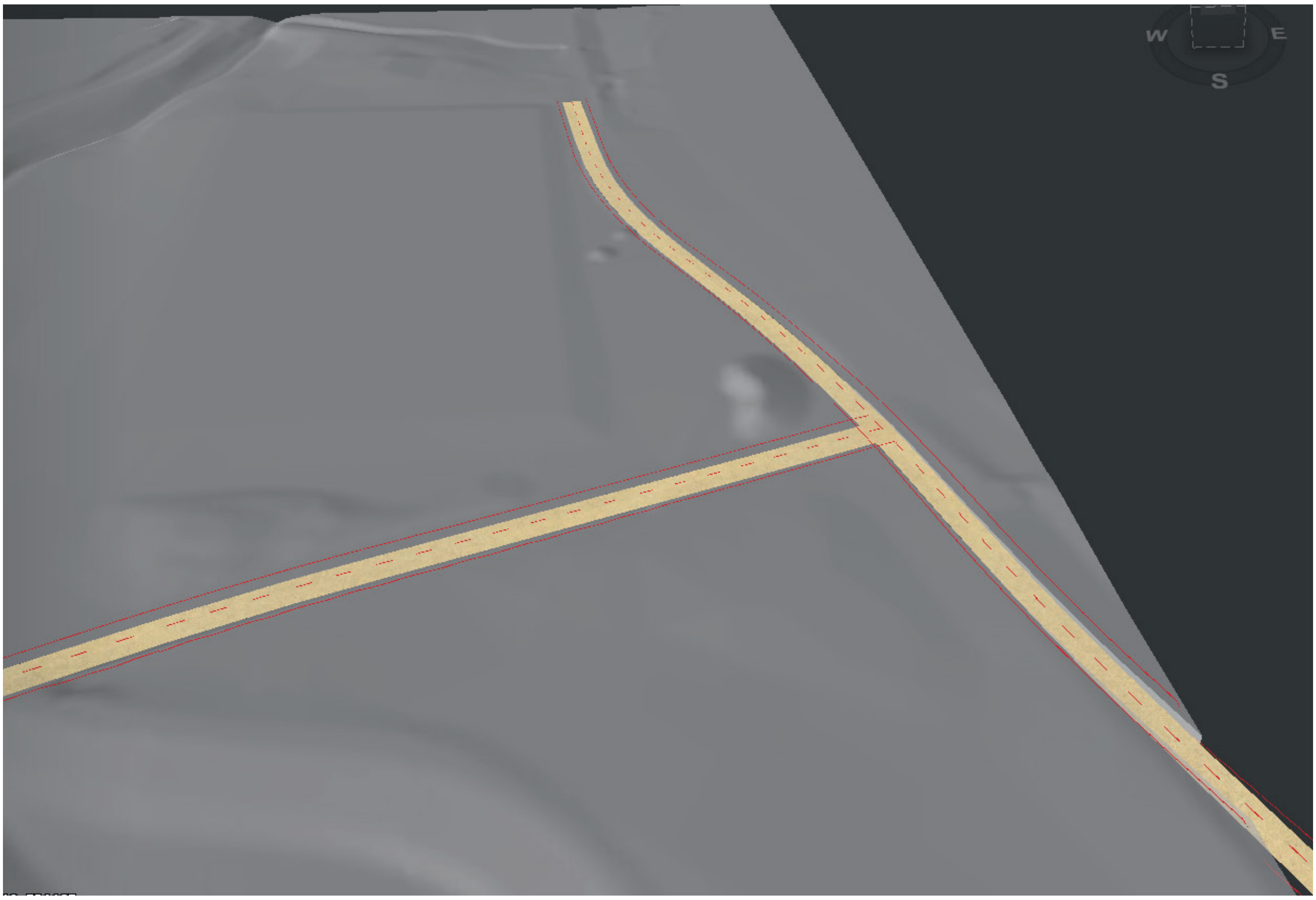
2 Knowledge.autodesk.com. (no date). Projecting 2D line or polyline onto Civil 3D surface. https://knowledge.autodesk.com/support/civil-3d/troubleshooting/caas/sfdcarticles/sfdcarticles/Projecting-2D-line-or-polyline-onto-surface.html Accessed 28.7.2019.



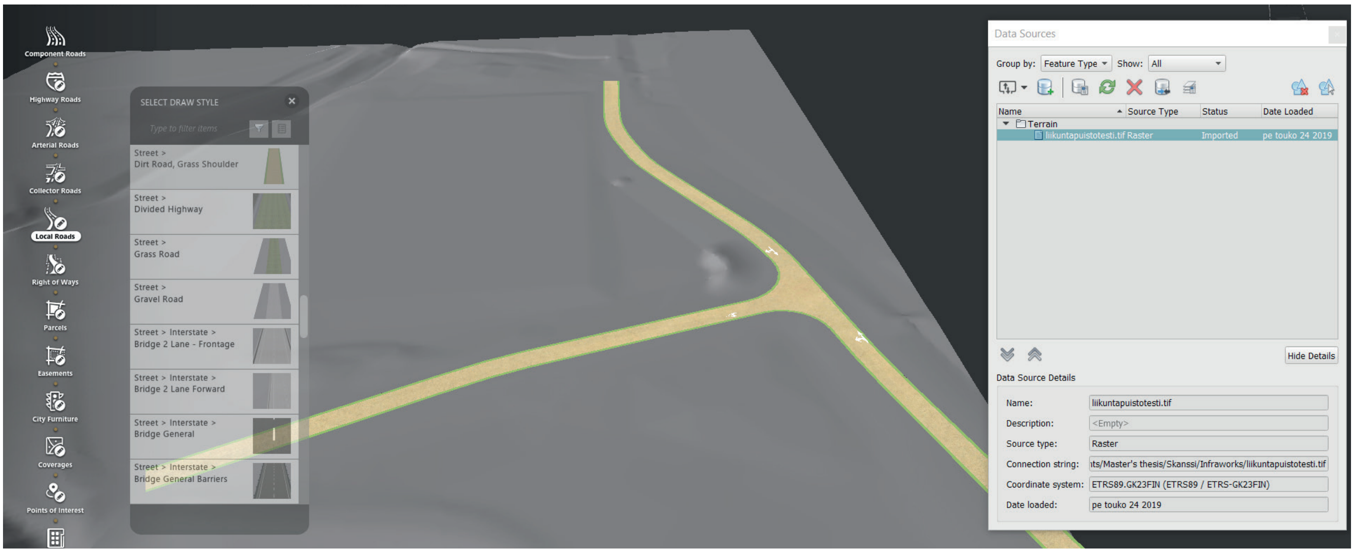
Path outlines shown on Civil 3D surface.

Infraworks:

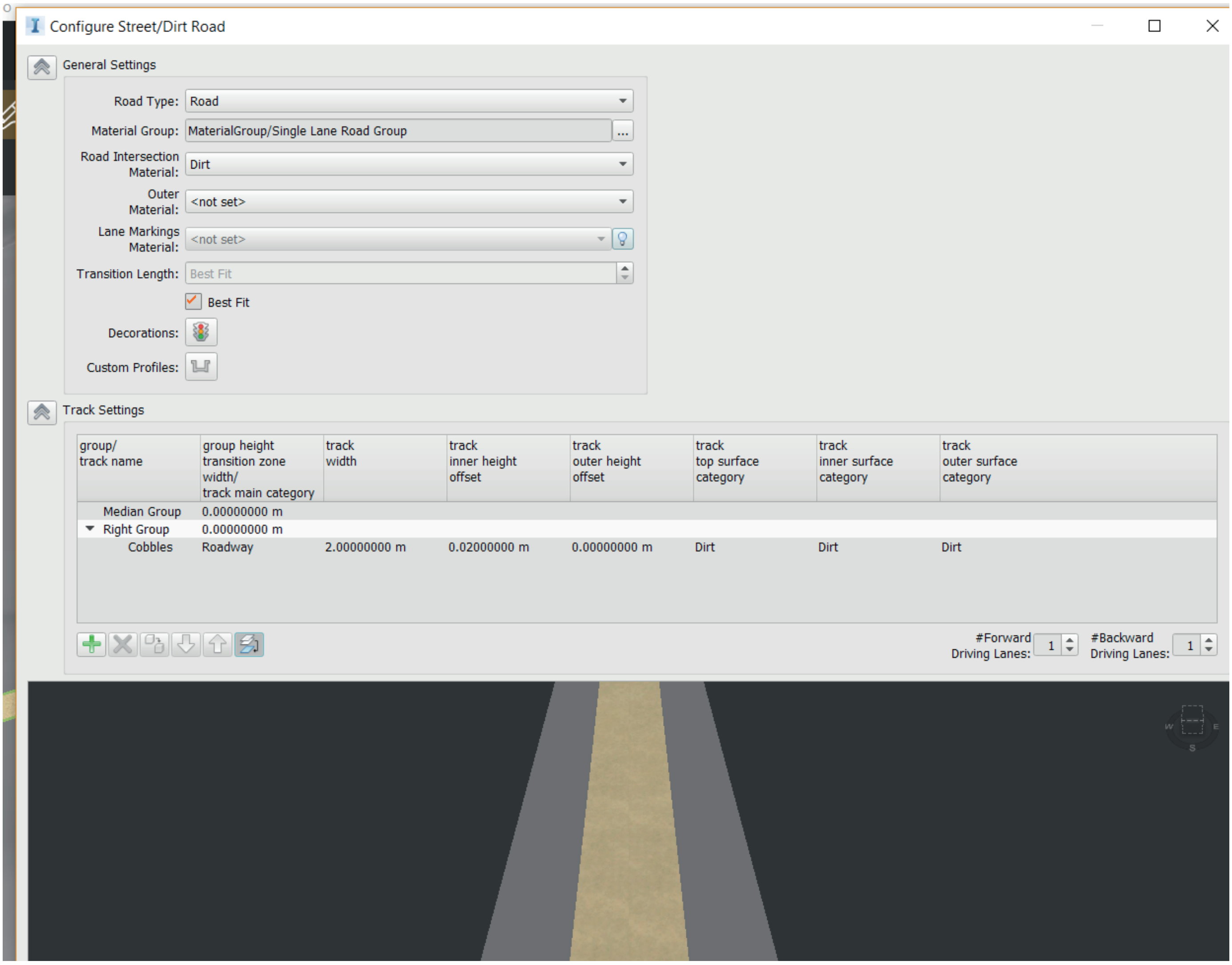
Infraworks has parametric road objects that can be used to draw roads. There are two options: planning roads or component roads. The road can be drawn onto the terrain in freeform, or exported lines can be used as the centerline of the road.



Above is shown a planning road. Planning roads are simple 2D roads projected onto the terrain.



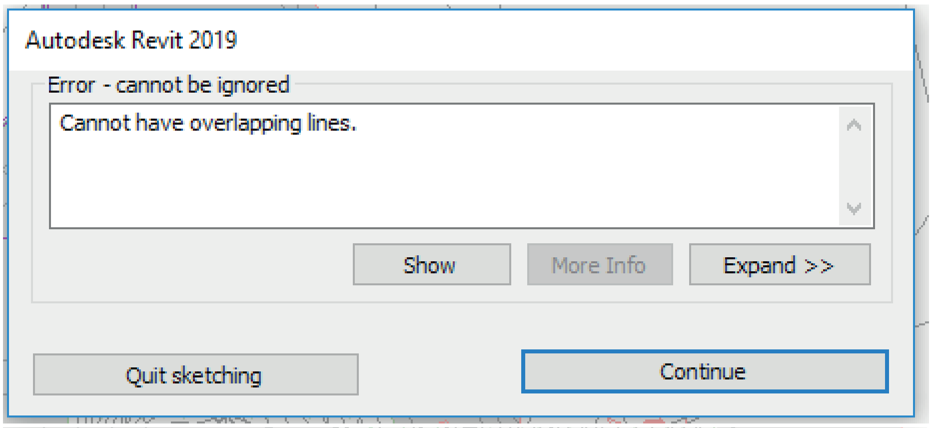
Component roads are parametric objects that also adjust the vertical and horizontal geometry of the terrain. Above is shown a component road. Below are shown the adjustable parameters of a component road.

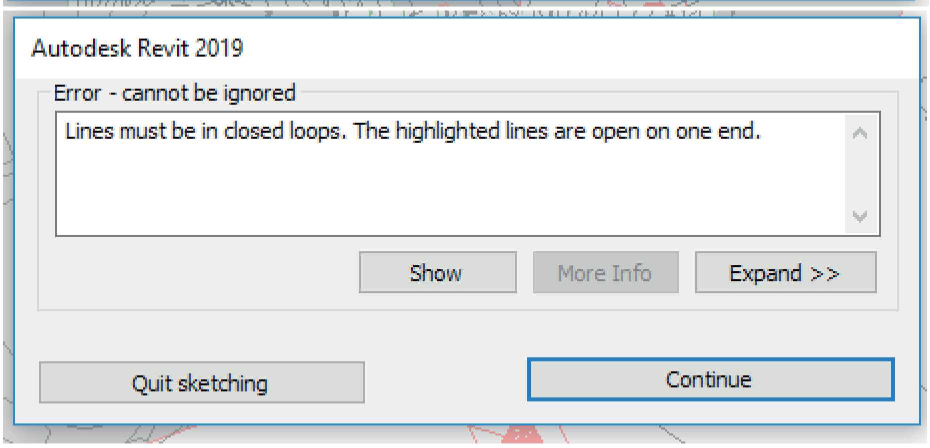


Revit:

In Revit roads can be made by splitting the terrain into separate surfaces or outlining subregions in the terrain (toposurface). However, the Site Designer extension for Revit has extensions. These will be looked at later in the conclusions chapter.

Subregions above as depicted in the Revit manual. [1] They can be set to have different colors and materials.





Projecting the outlines to the topography in order to create a subregion can be tedious due to the difficulty of selecting chains of lines to project, as shown above. All lines must be connected and all shapes must be closed. This method is highly reliant on the integrity of the original ground plan file.

---

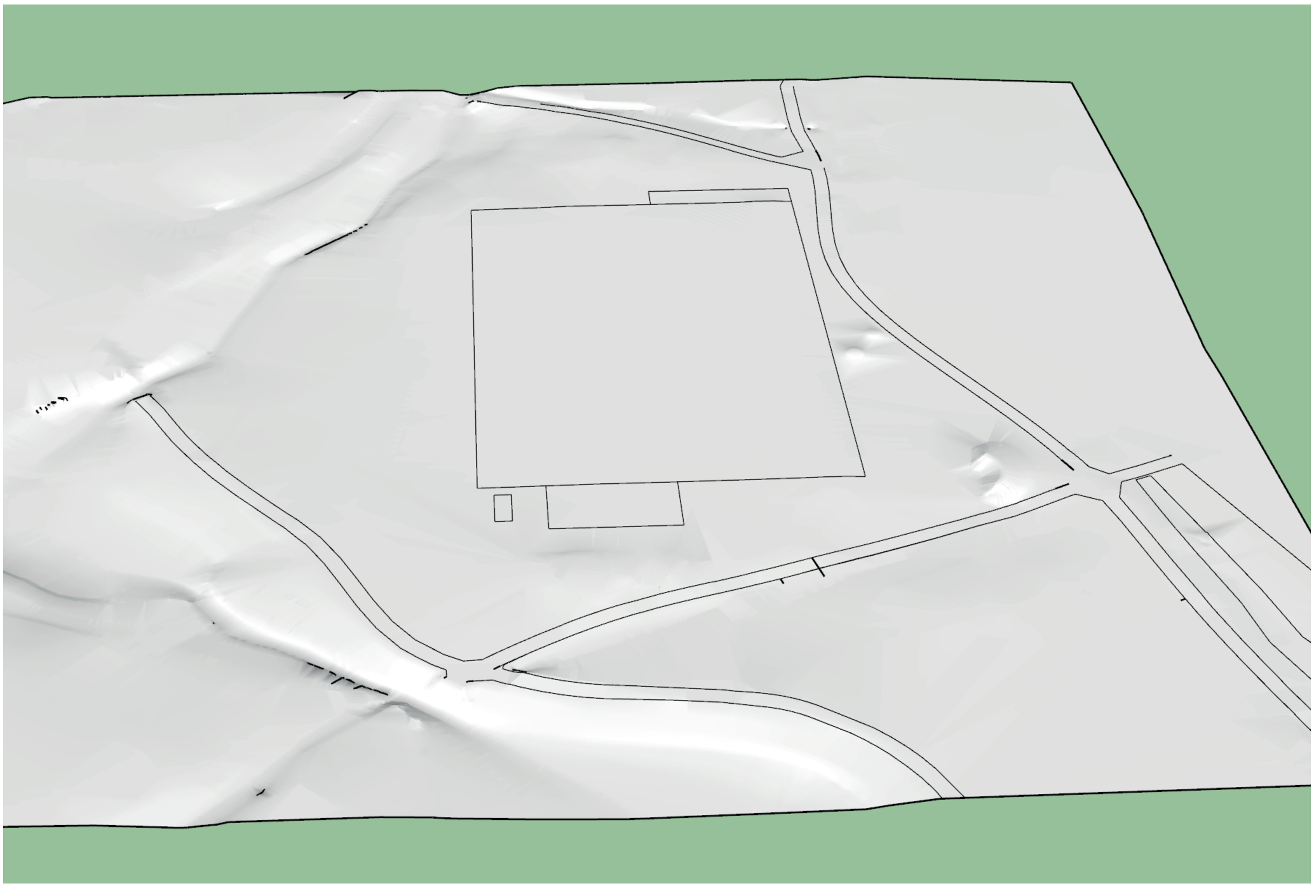
1 Knowledge.autodesk.com. (no date)., Create a Toposurface Subregion. https://knowledge.autodesk.com/support/revit-lt/learn-explore/caas/CloudHelp/cloudhelp/2018/ENU/RevitLT-Model/files/GUID-CE895A23-9BF3-479B-B750-360F27AB825B-htm.html Accessed 28.7.2019.

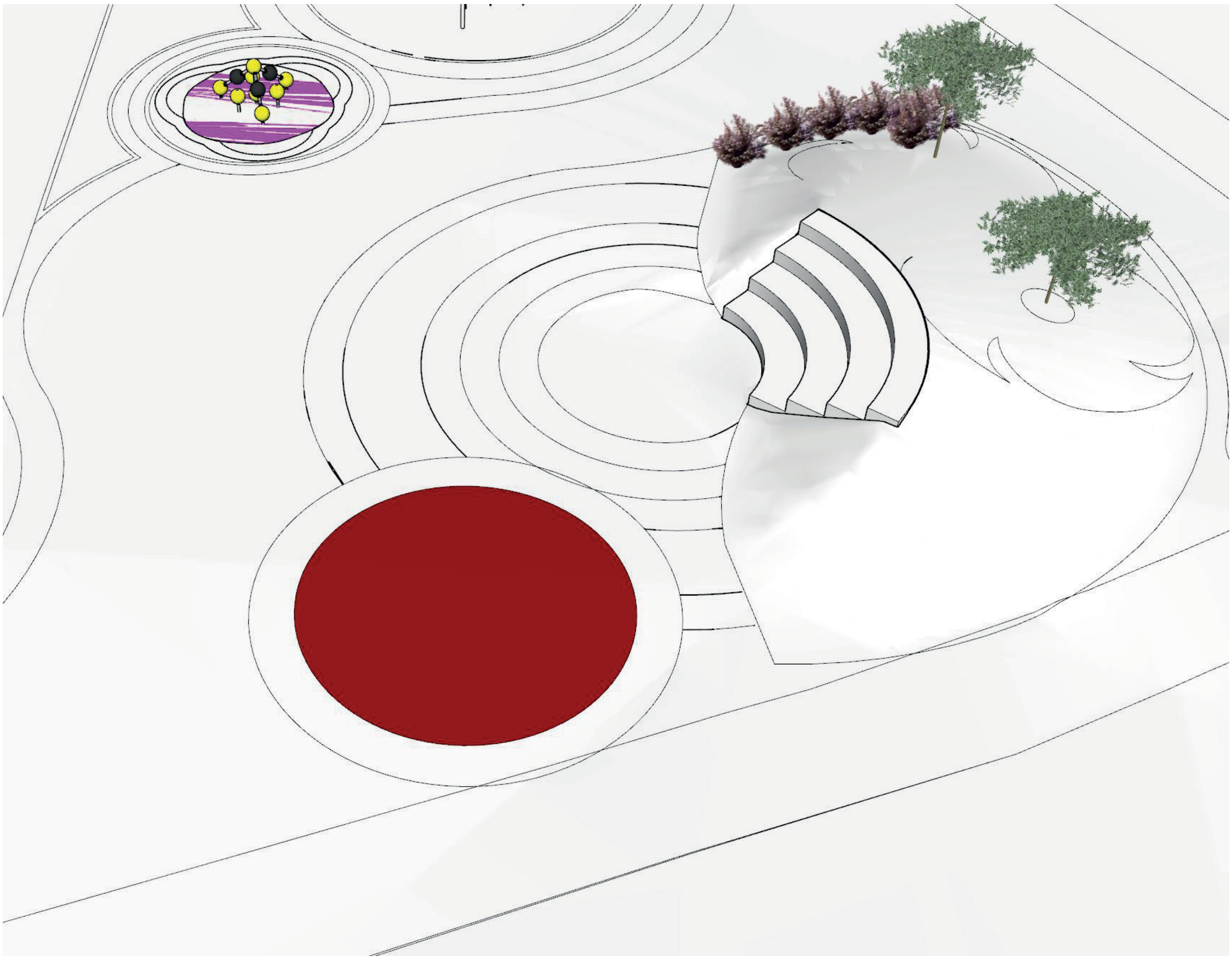
Rhino 3D:

In Rhino road outlines can be projected onto a NURBS surface and then be split into a separate surface, if needed. A separate surface can have a different color and material. Lands Design for Rhino has path tools. These will be looked at later in the conclusions.

Sketchup:

In Sketchup road outlines can be projected onto a TIN surface with the drape tool.





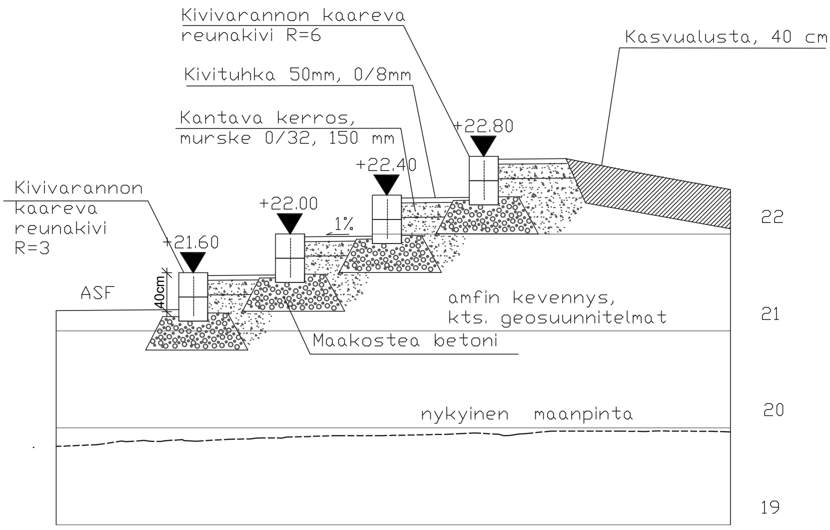
Closed shapes can be colored to distinguish them from the surroundings, as shown above.

3.2. Verdicts

3. Other elements of landscape design	Civil 3D	Infraworks	Revit	Rhino 3D	Sketchup Pro
3.2. Routes	Can project as lines. Can create as separate surface for coloring. Extensive tools for determining road slopes, sections, etc.	Can project as lines. Parametric tools for roads (including sections).	Cannot project as lines, but can make sub-surface or split for coloring. However, the selection method is slow.	Can project as lines. Can split into separate surface for coloring.	Can project as lines. Cannot split into separate surface, but can color with a material.

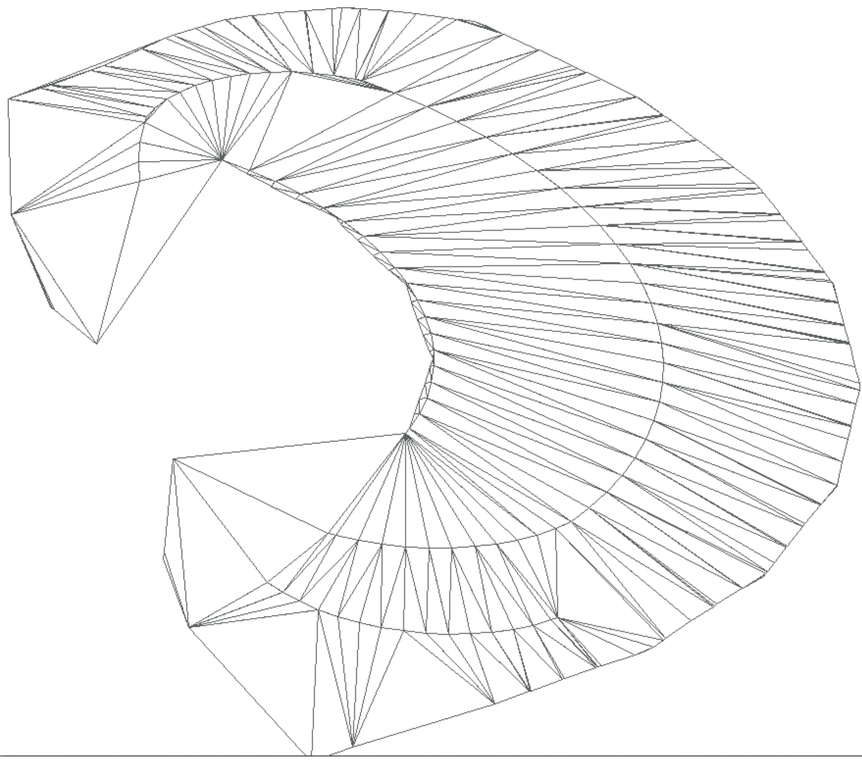
3.3. Structures (amphitheater + terrain modification)

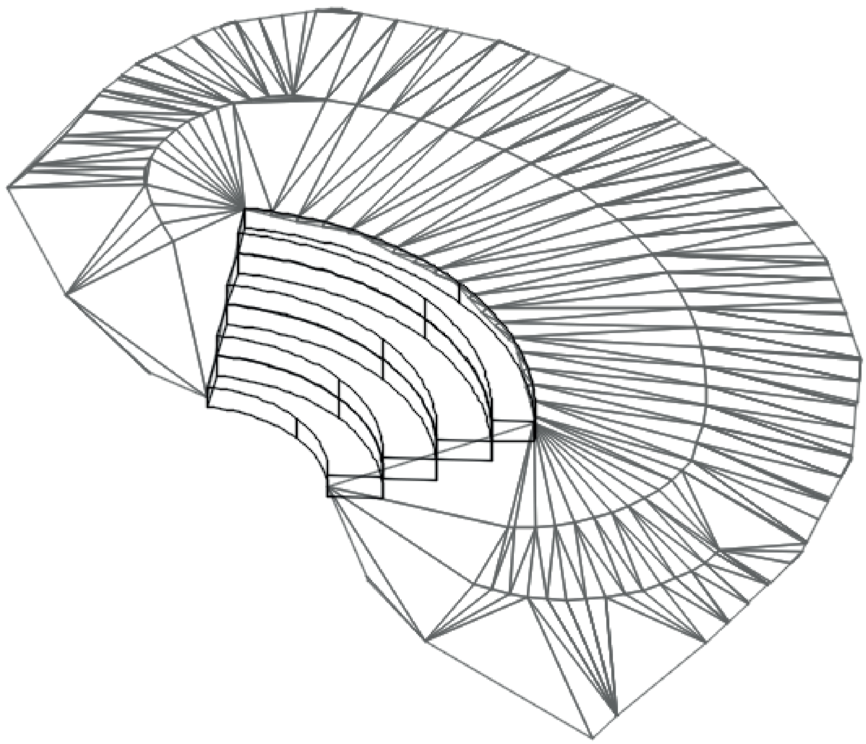
In this task, modeling the amphiteater is attempted. Below a structural section of the amphiteater is shown. Usually this level of detail is not required in the 3D model, so a visual representation is aimed for instead. It should be possible to represent the seating stairs embedded into the landform.



Civil 3D:

The landform of the amphitheater was created using breaklines with set elevations.

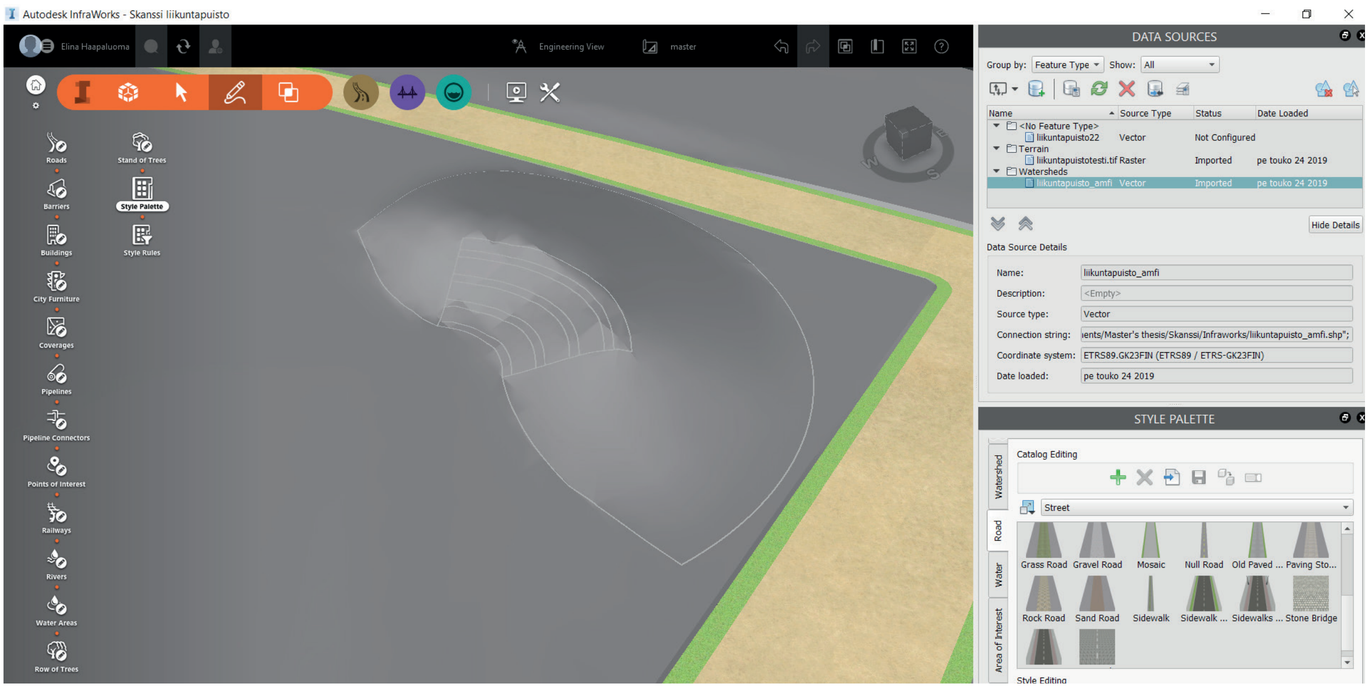


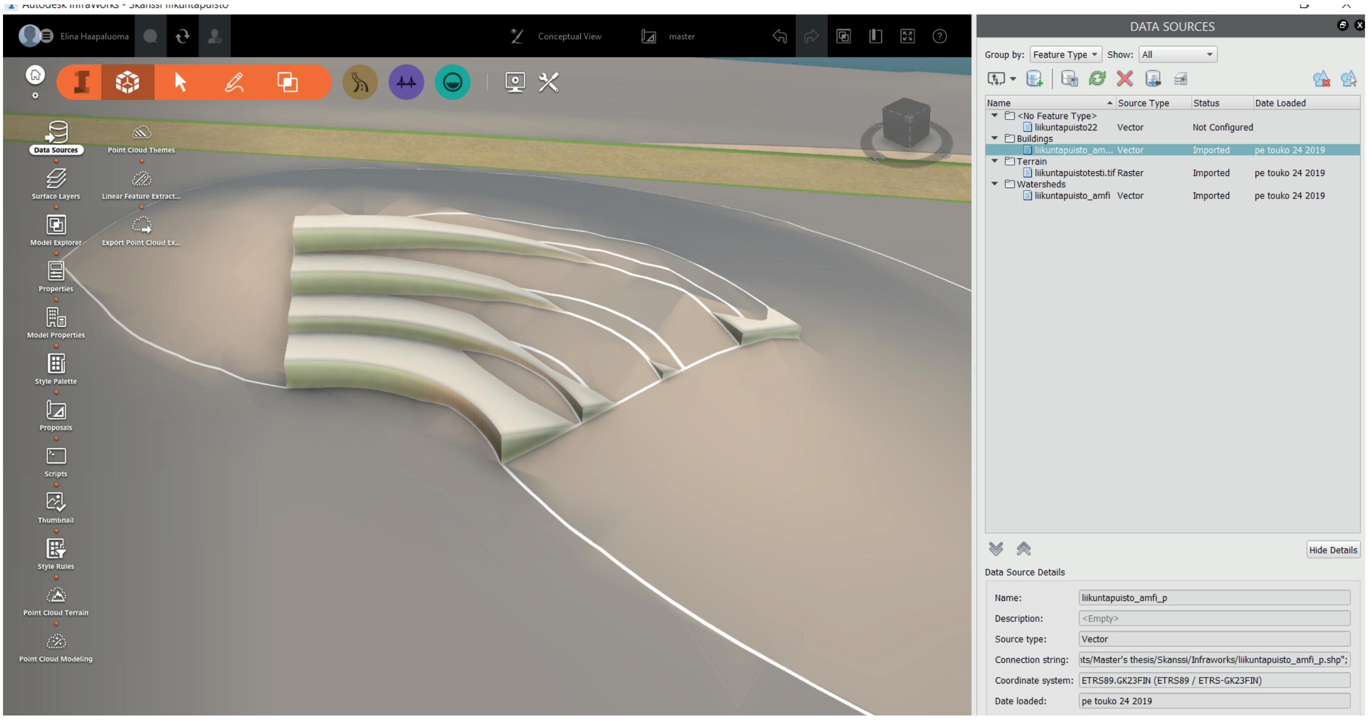


The stairs used for sitting were created by extruding the polygons and lifting them to the correct height in perspective view.

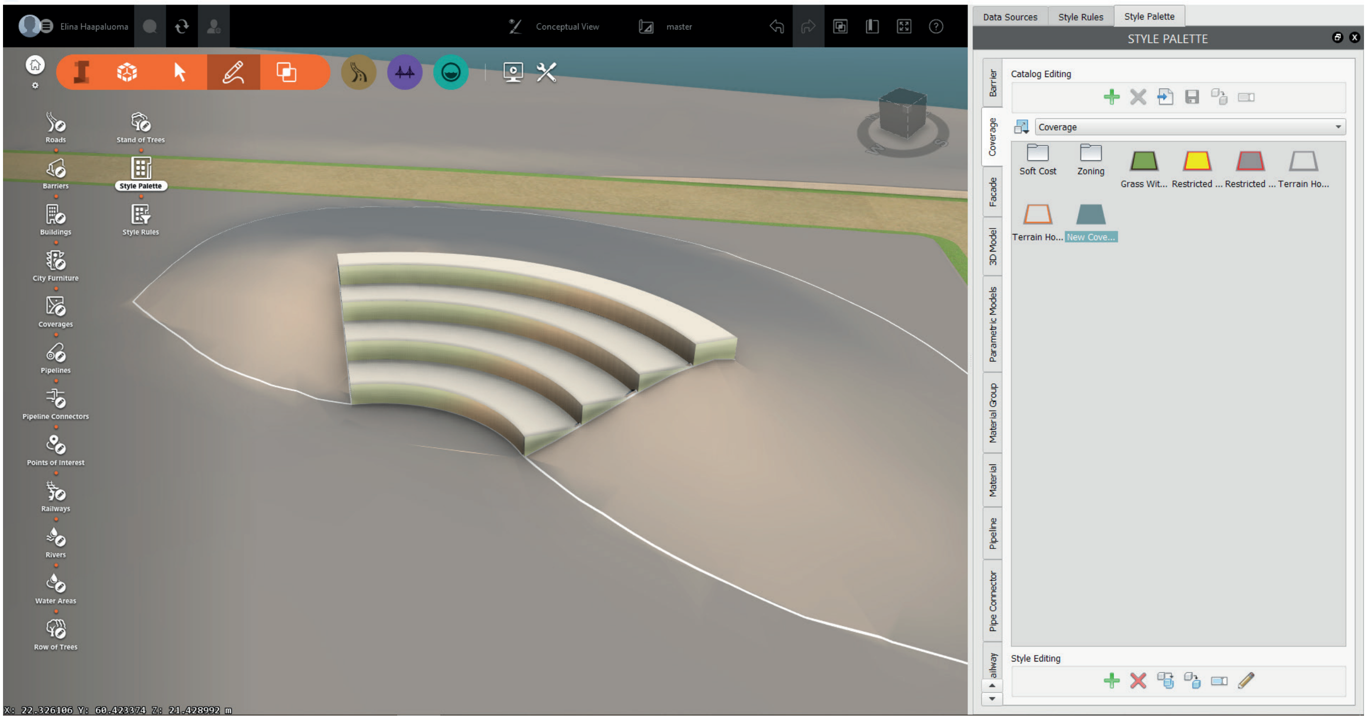
Infraworks:

The landform has to be exported as a ready 3D model. This was exported from Civil 3D as a TIF file. The outlines were exported as SHP files.





To visualize the stairs in Infraworks, they could be brought in as a ready 3D model. However, in this case, the outlines were imported as SHP files. These outlines were made as closed polygons, so that Infraworks could construct them as buildings, shown above.

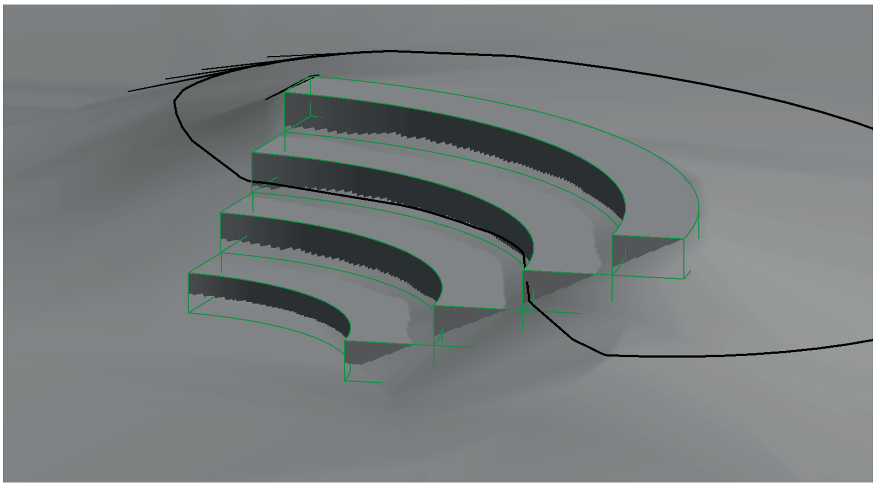


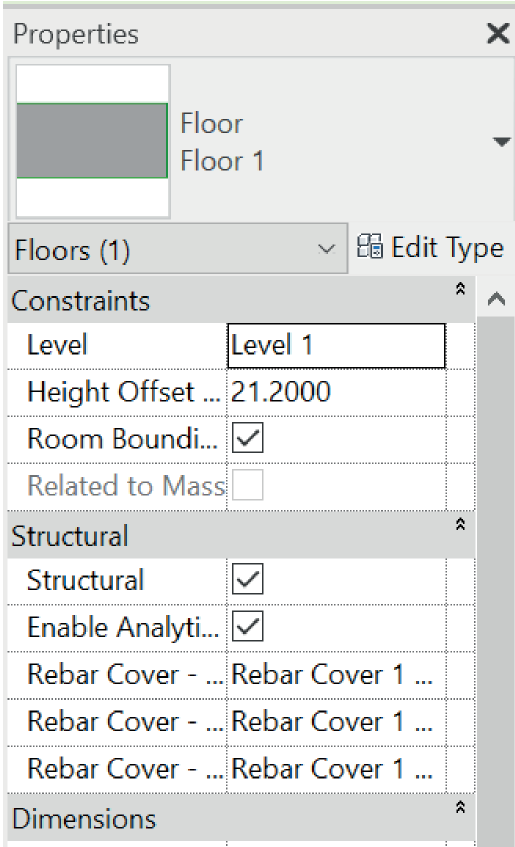
Using the Coverage tool, a dent was created in the terrain, so that the stairs would not sink in. Then the stairs were lifted to desired heights.

Revit:

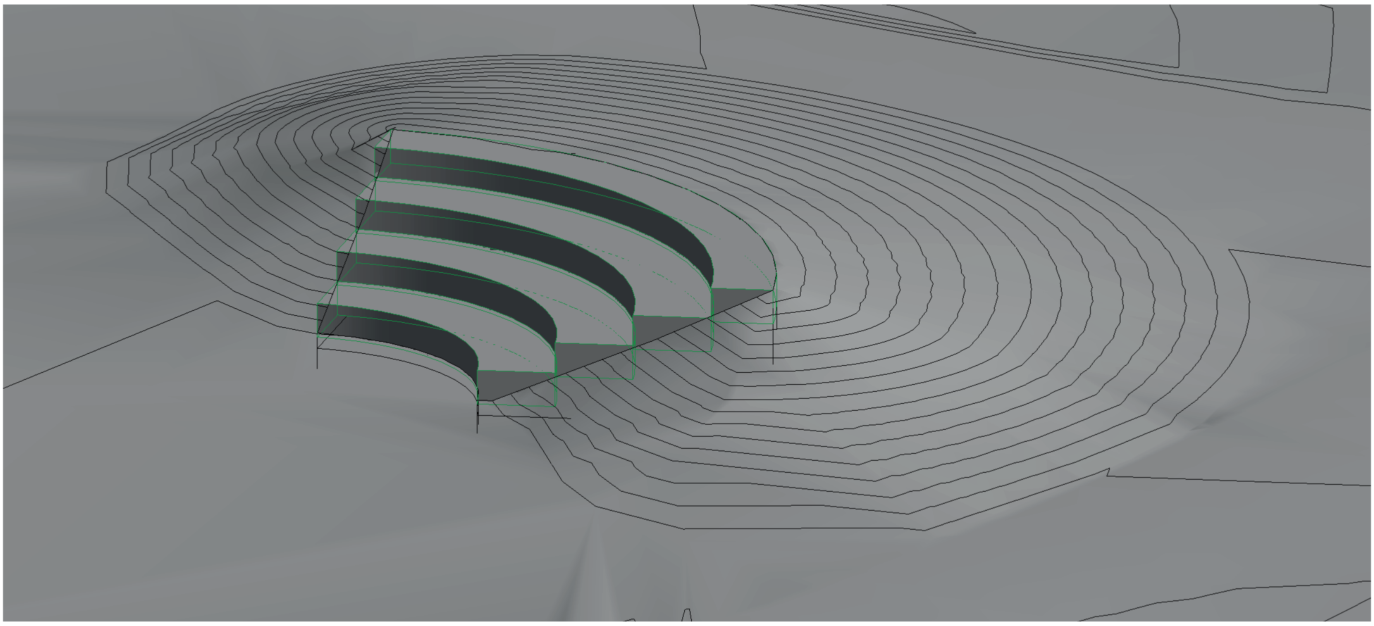
The landform must be created using contours or by exporting the terrain as a 3D model. Several parametric objects in Revit can be used to construct the stairs in this case. Among them are beams, walls, floors or In-Place Components. In this case, floors were seen to be most suitable.

The floors can be lifted to correct height using the absolute height as measured from the sea level in the Properties panel as shown beside.



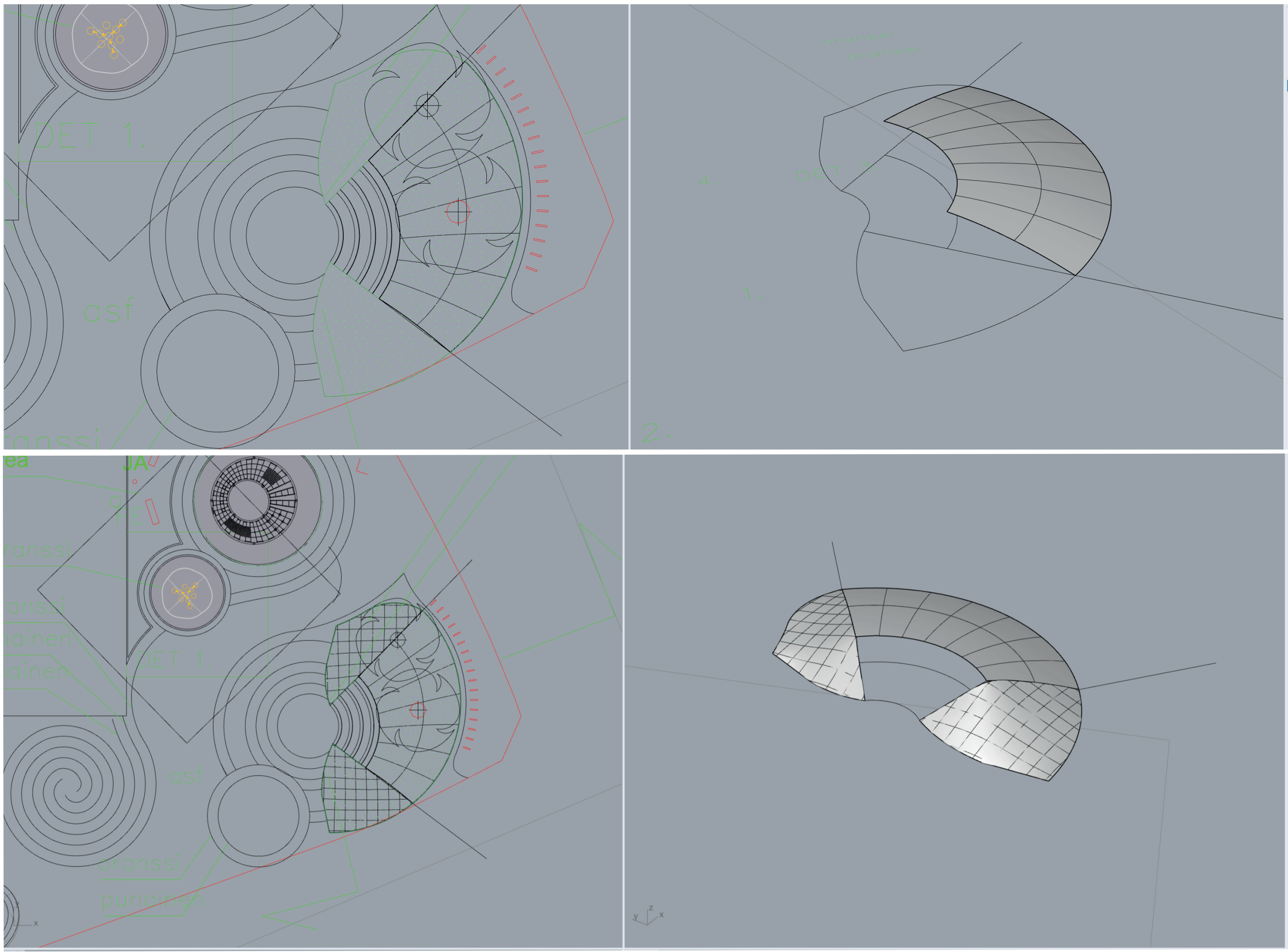


Below, a building pad was used to create a dent in the terrain for the stairs.

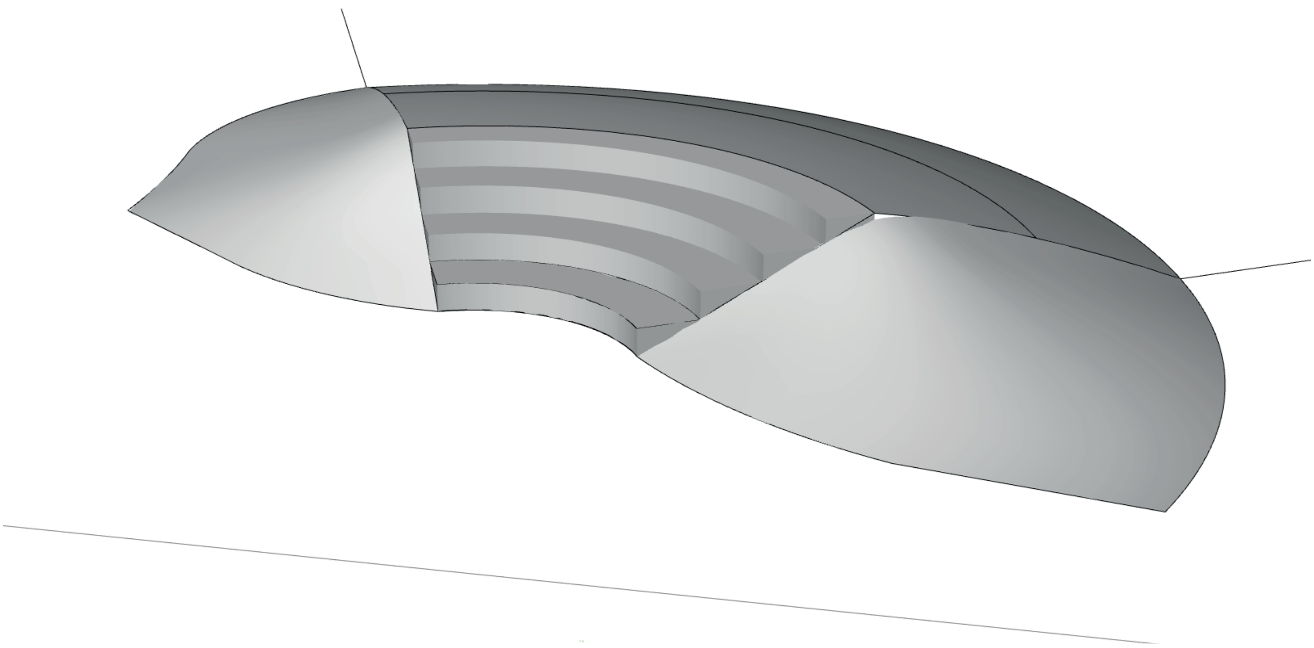


Rhino 3D:

The landform can be made from scratch, resulting in a very smooth NURBS model. In this demonstration, shown below, the loft and patch tools were used.

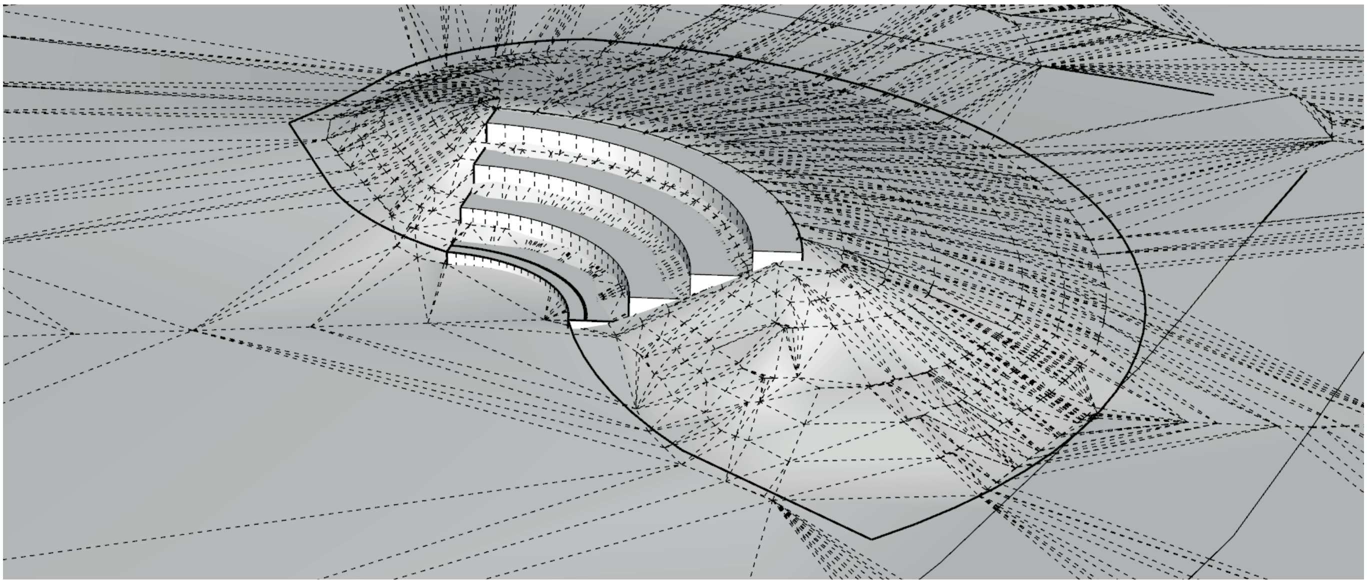


The stairs were extruded and lifted to the correct height using relative heights, shown below.

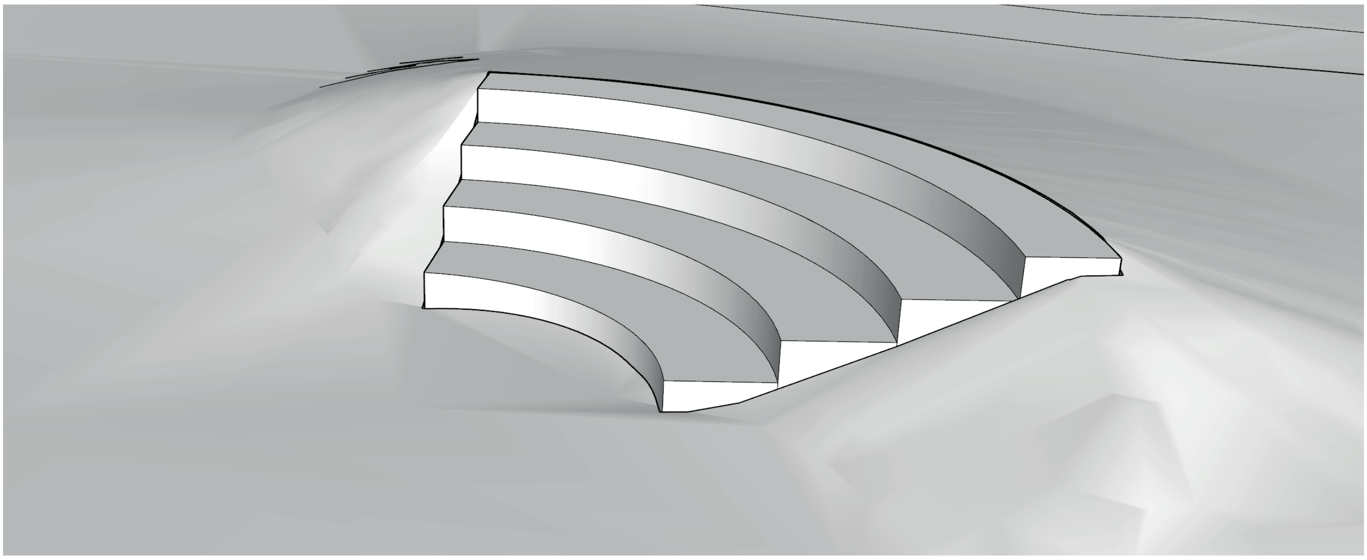


Sketchup:

The landform must be created using contours or by exporting the terrain as a 3D model. The stairs were extruded and lifted to the correct height using relative heights.



An indent was created on the terrain with the stamp tool, shown below.



3.3. Verdicts

3. Other elements of landscape design	Civil 3D	Infraworks	Revit	Rhino 3D	Sketchup Pro
3.3. Structures (amphitheater)	Seating stairs as extrusion. Landform from breaklines and feature lines.	Seating stairs as buildings. Landform must be exported.	Seating stairs as floors. Landform from contours.	Seating stairs as extrusion. Landform from construction lines. Gives the smoothest result.	Seating stairs as extrusion. Landform from contours.

3.4. Playground equipment / street furniture

In a sports park the sports equipment plays a large role, so it is important to be able to visualize them. One requirement in representing furniture is the ability to place the furniture models on top of the terrain. The efficiency of completing this task affects the workflow.

The manufacturers of street furniture usually have 3D models of their products on their website in CAD format. These can be used to visualize the end result. If the landscape 3D model is intended for visualization purposes, the furniture 3D models should retain their materials. However, some software may have problems with importing the CAD 3D models.

To the right are listed the playground equipment and street furniture that were used in the sports park design. 3D models could only be found on the playground equipment, not on the street furniture. However, the playground equipment plays a larger role in this plan, so that will be the focus of this evaluation.

PLAYGROUND EQUIPMENT

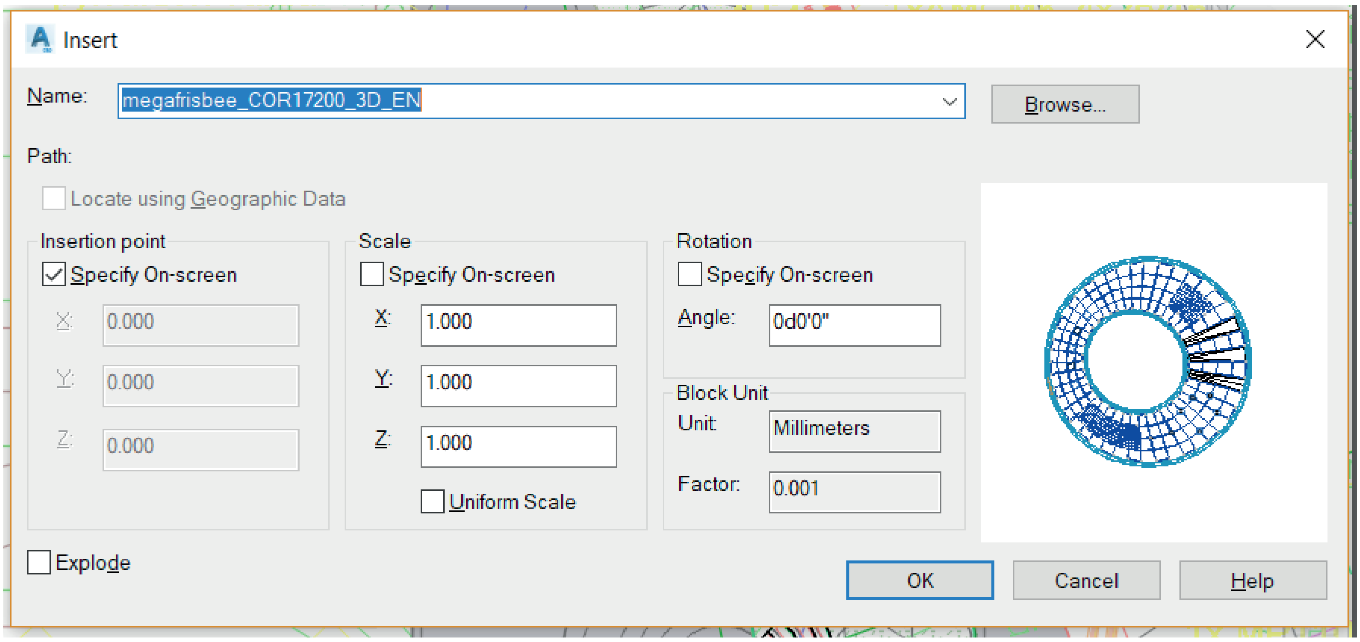
1. Mega Frisbee, Kompan, COR172001-1102
2. Pyramid Climber, Lappset, 220505
3. Street workout M, Lappset, 081655M
4. Precision Beam, Lappset, 220541
5. Metalliareena, Lappset, 080851

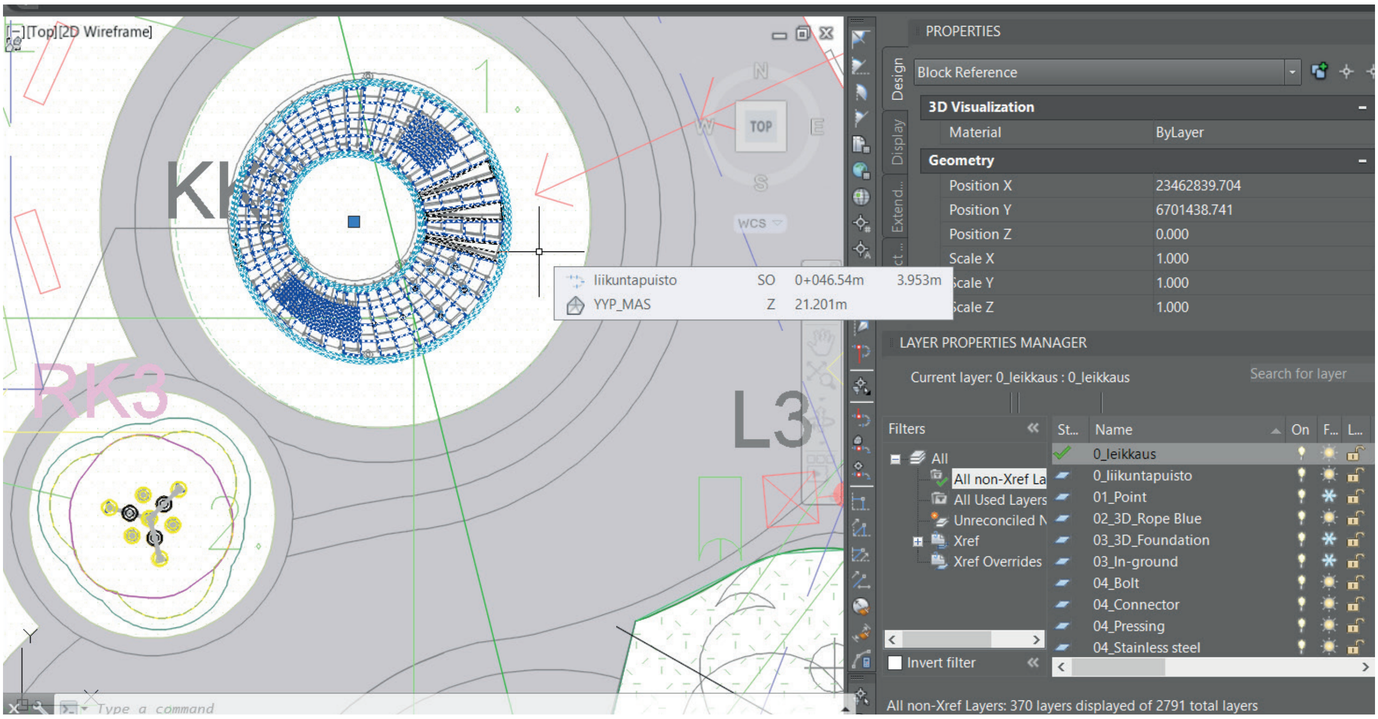
STREET FURNITURE

PE Bench, Streetlife, Rough and ready
RO Trash can, Vitreo Nola Elbin, 30C
PY Bicycle rack, Street life, corten bicycle rack, metal

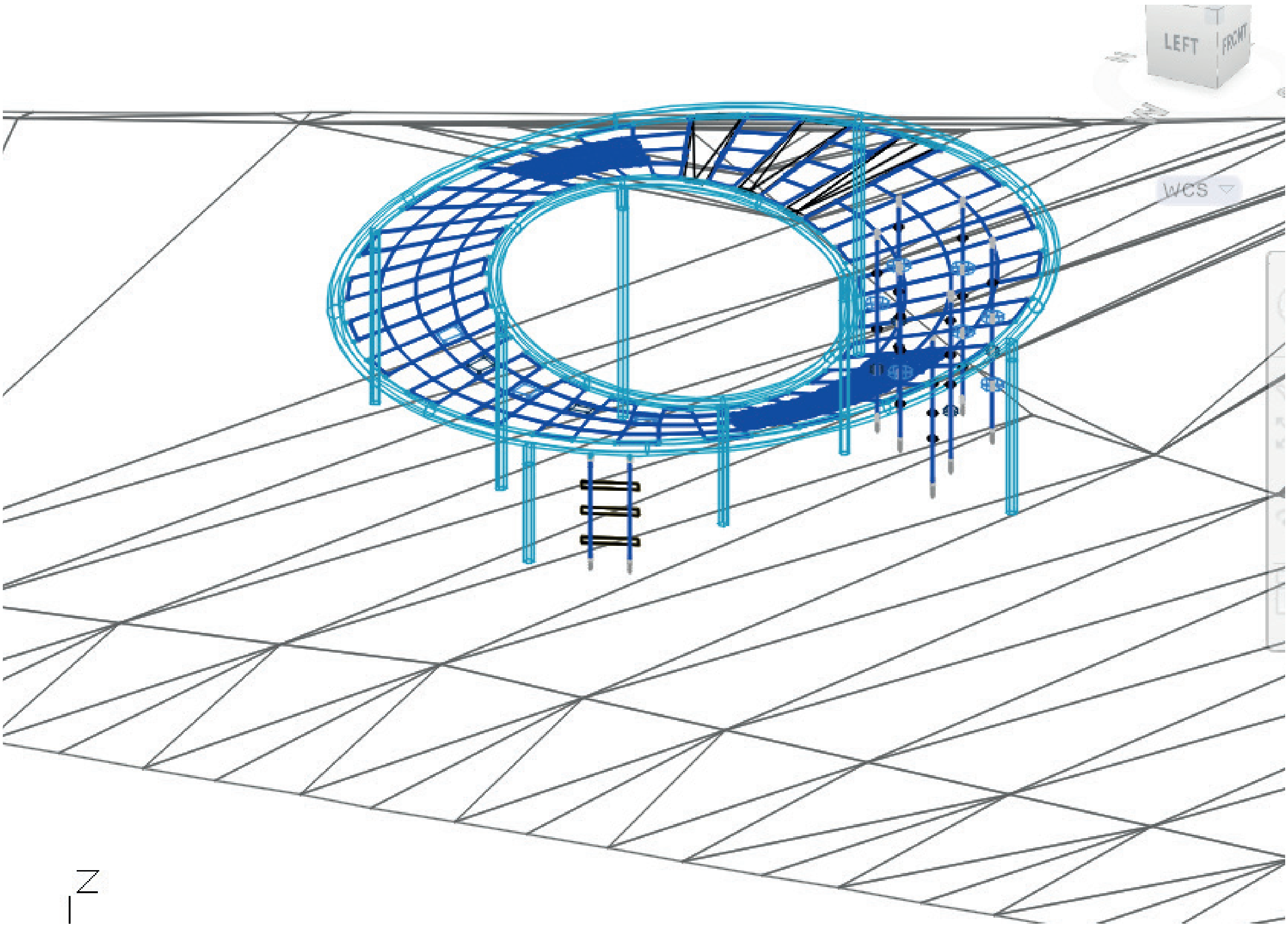
Civil 3D:

In Civil 3D the sports equipment can be placed as blocks, as shown below. They come in DWG format, which is the native file format of Civil 3D, meaning that they will retain all materials originally assigned.

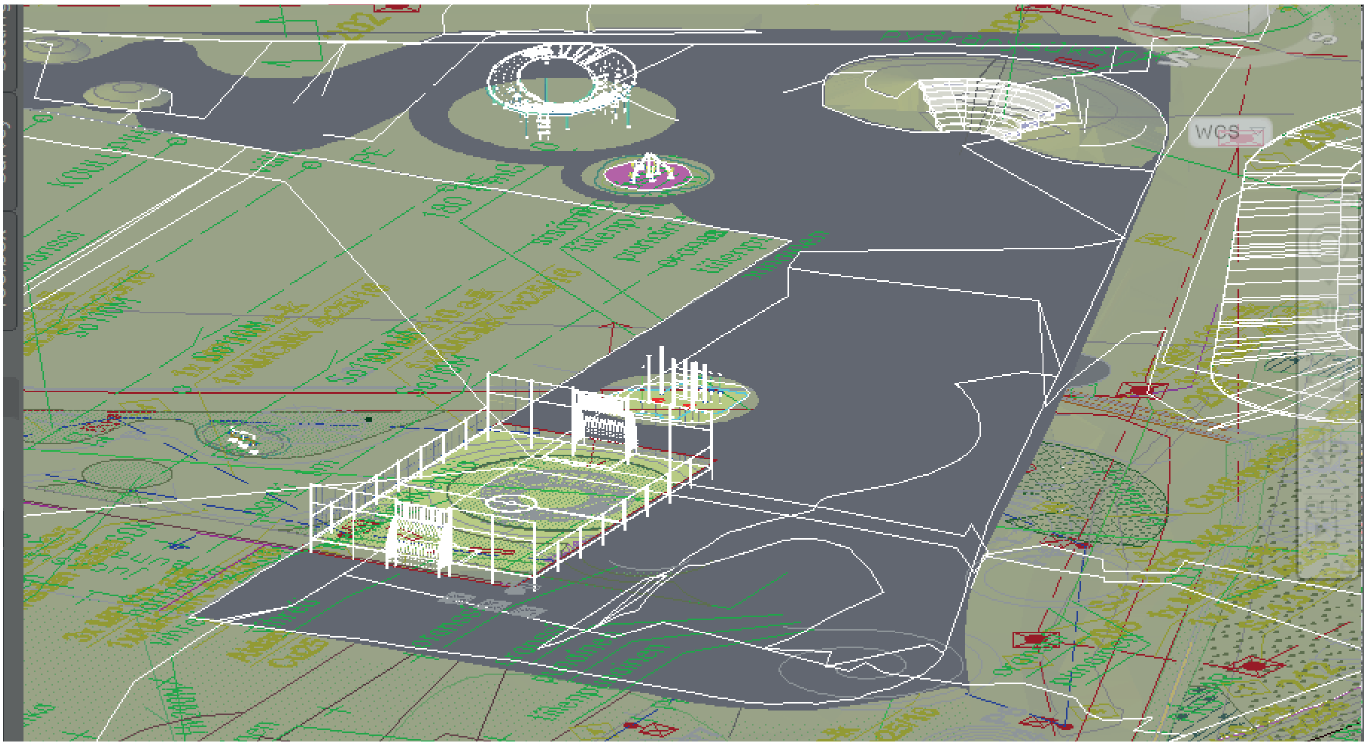




These height of the blocks can be directly input in the properties as the Z value, as shown above.



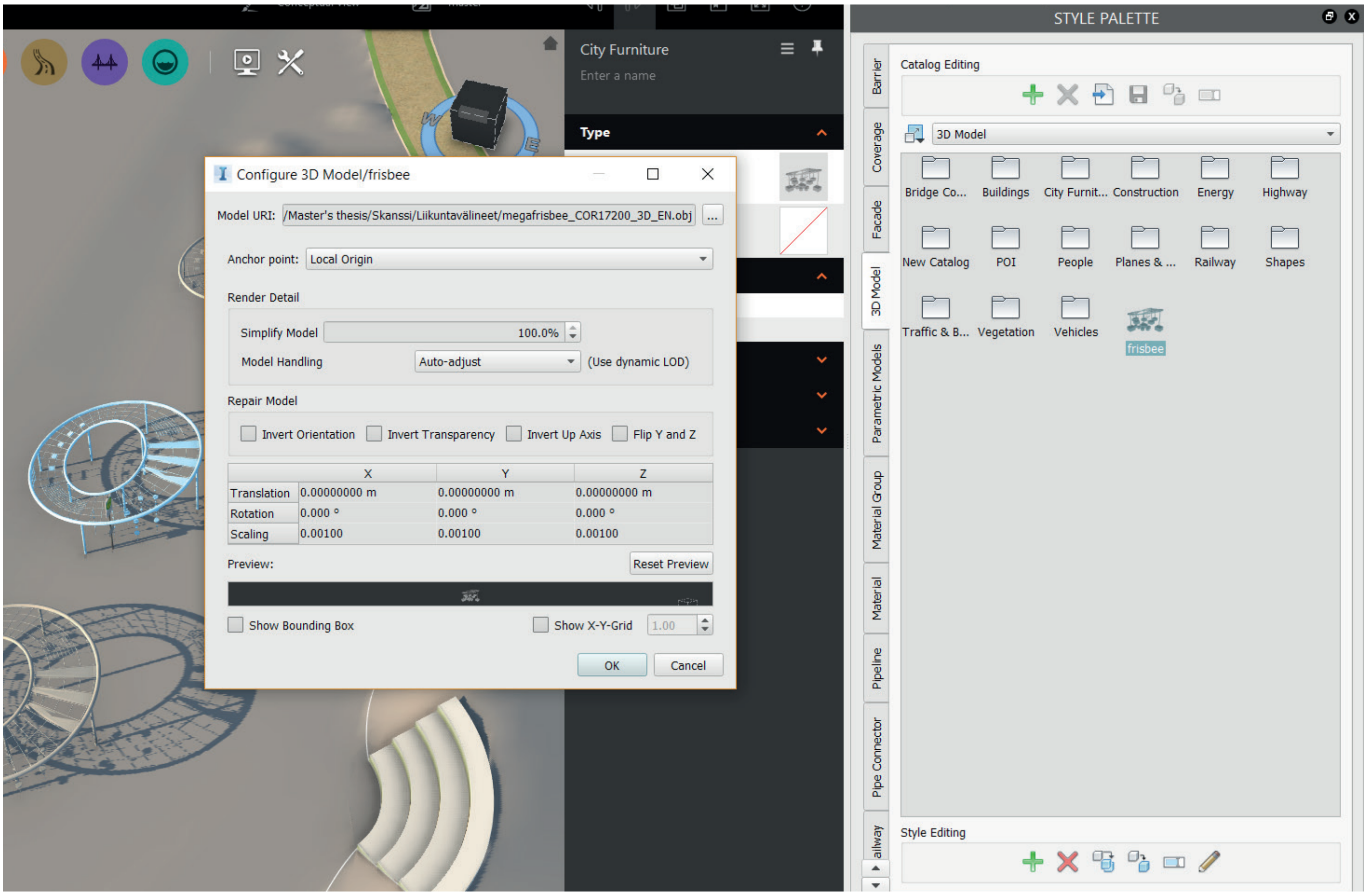
The mega frisbee placed on ground level.



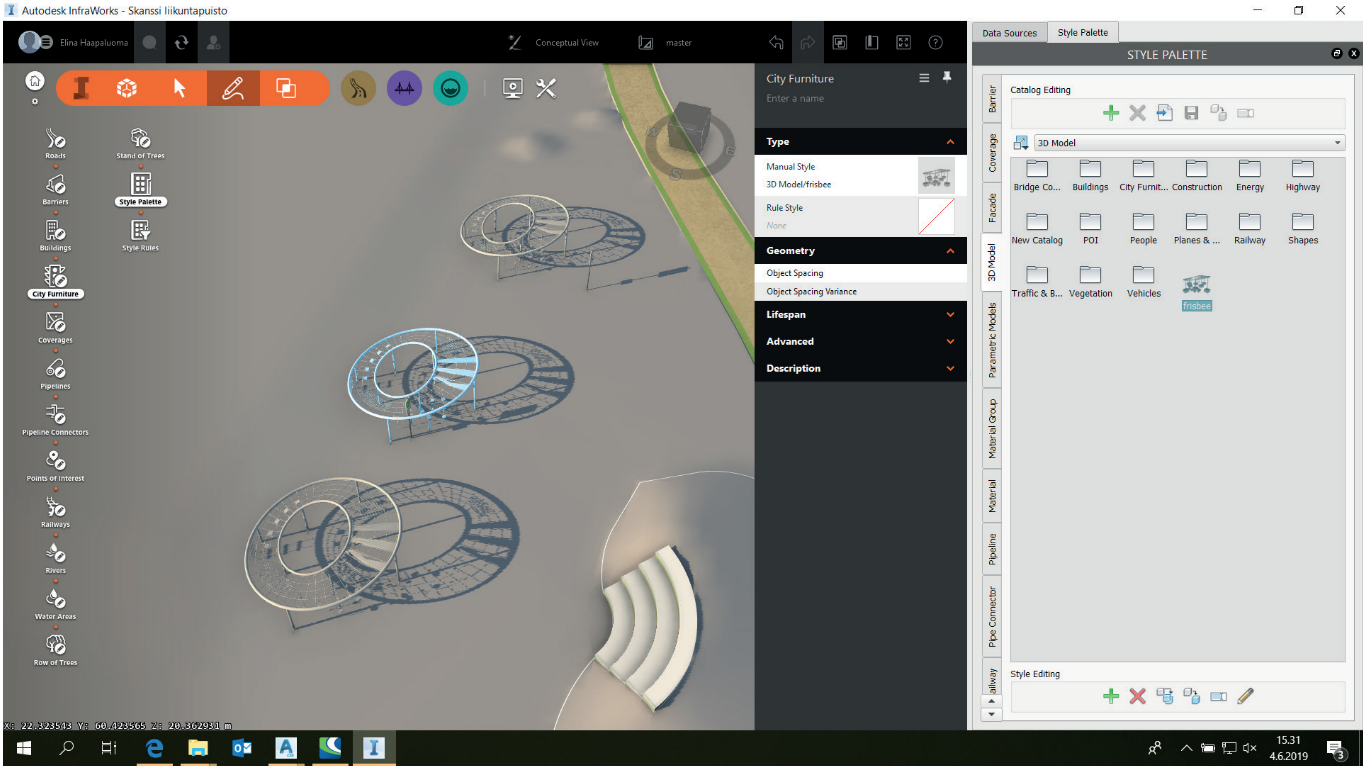
The rest of the equipment placed on ground level.

Infraworks:

Infraworks poses more problems, since the CAD objects have to be converted to a different 3D format. The mega frisbee was imported in OBJ format succesfully. However the other objects had problems. 3DS format was attempted and eventually FBX was settled on to import the rest of the objects.



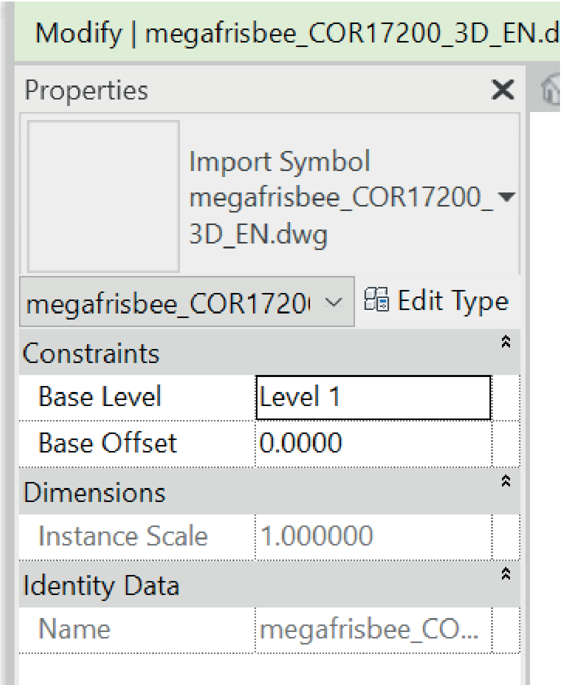
The settings of the object shown above.



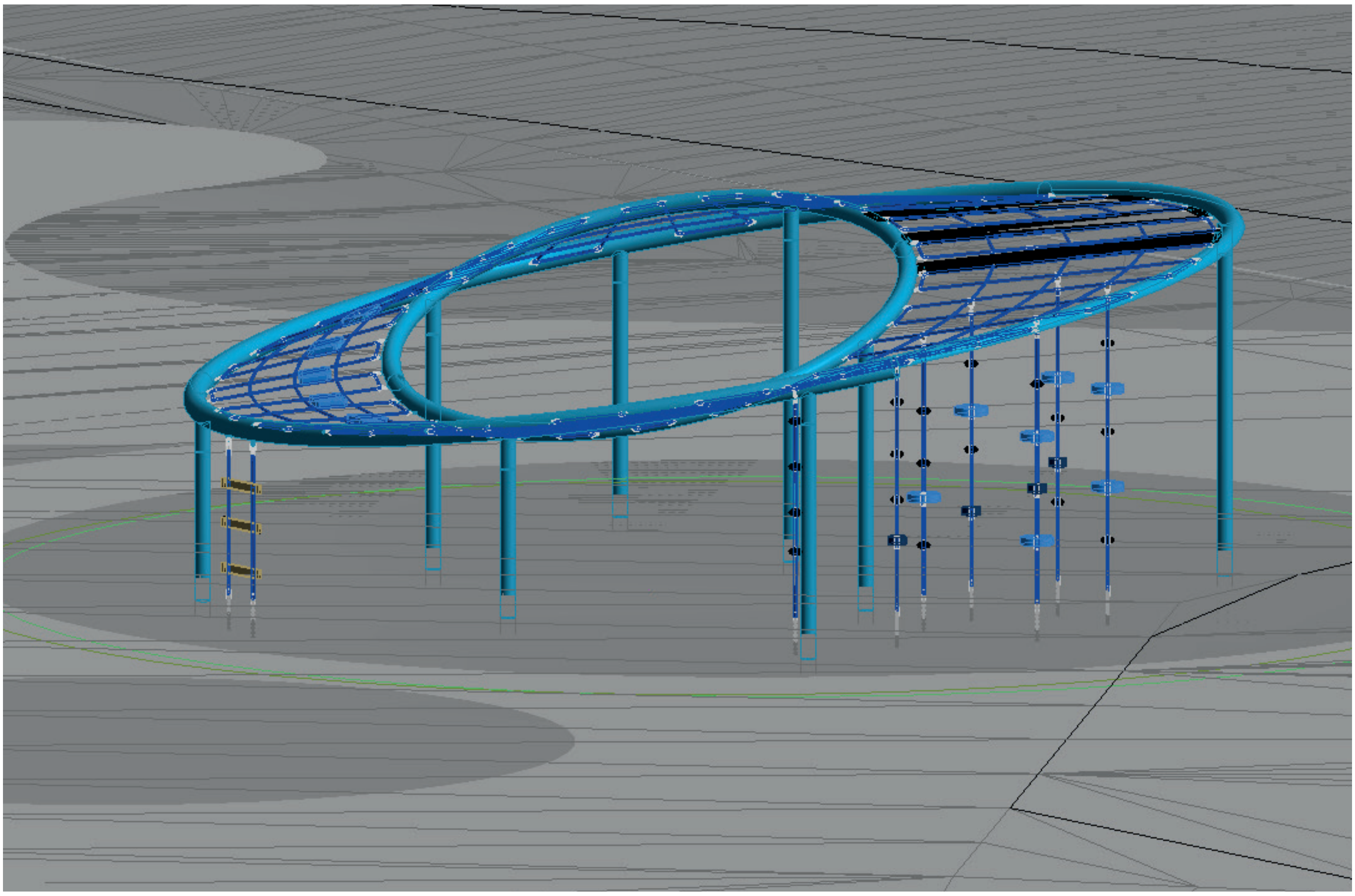
Mega frisbees set as placeholders shown above. Setting the objects on the ground is easy, since there are no height adjustments to be made. The software sets the objects on top of the terrain automatically. Below the placeholders have been replaced with the actual furniture. Note that the materials of the objects were not retained during exporting in this case. This is fixable, but not necessarily practical.

Revit:

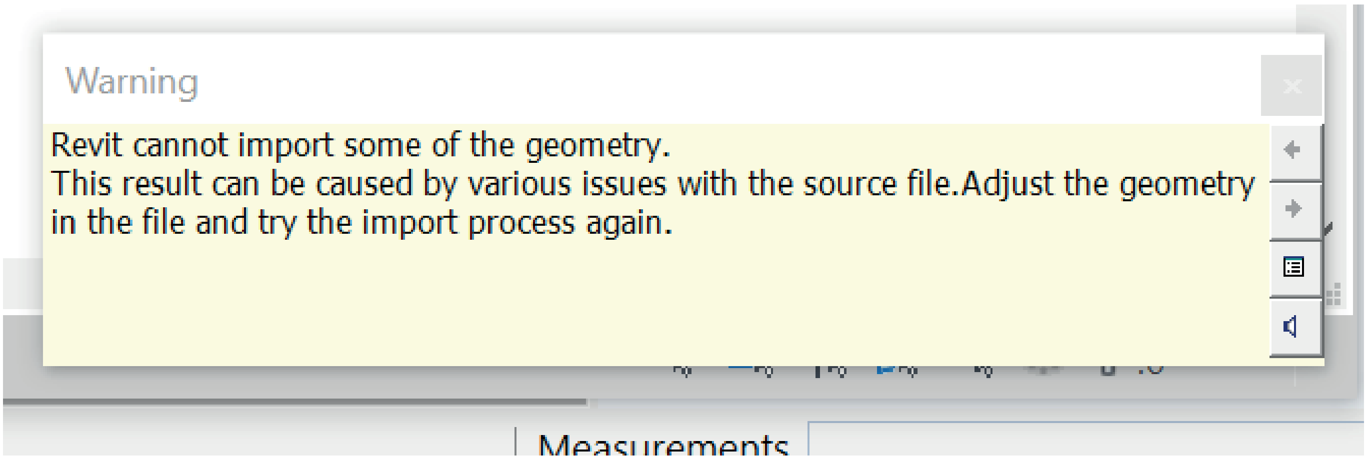
The objects are imported in CAD format. The mega frisbee was imported successfully, however loading took a long time.



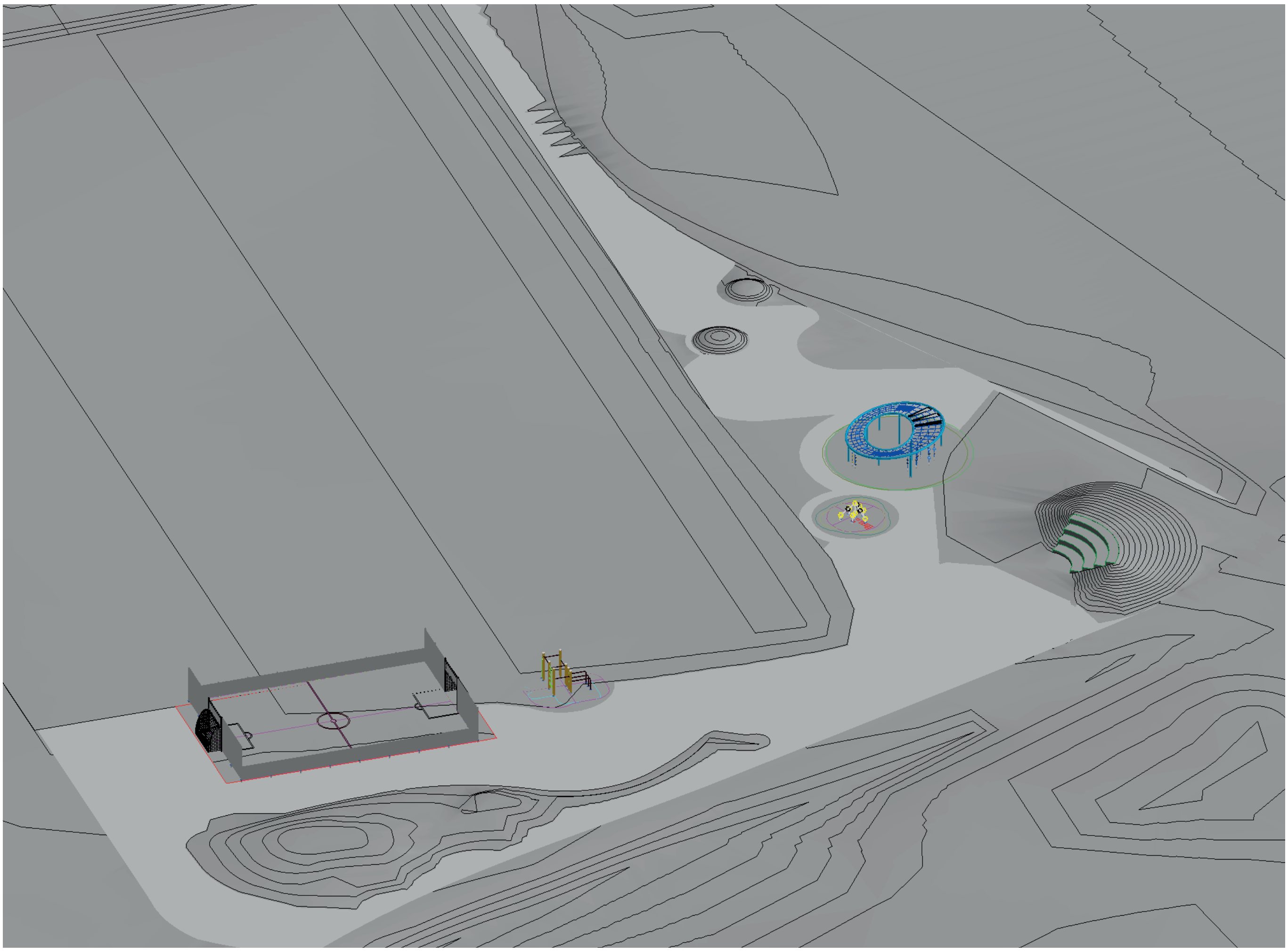
The height level of the object is directly input into the properties, as shown above. If the objects are imported as Revit “families”, they can be set on toposurface automatically.



The mega frisbee on ground level. As is shown, the materials are retained because no file conversion is needed.



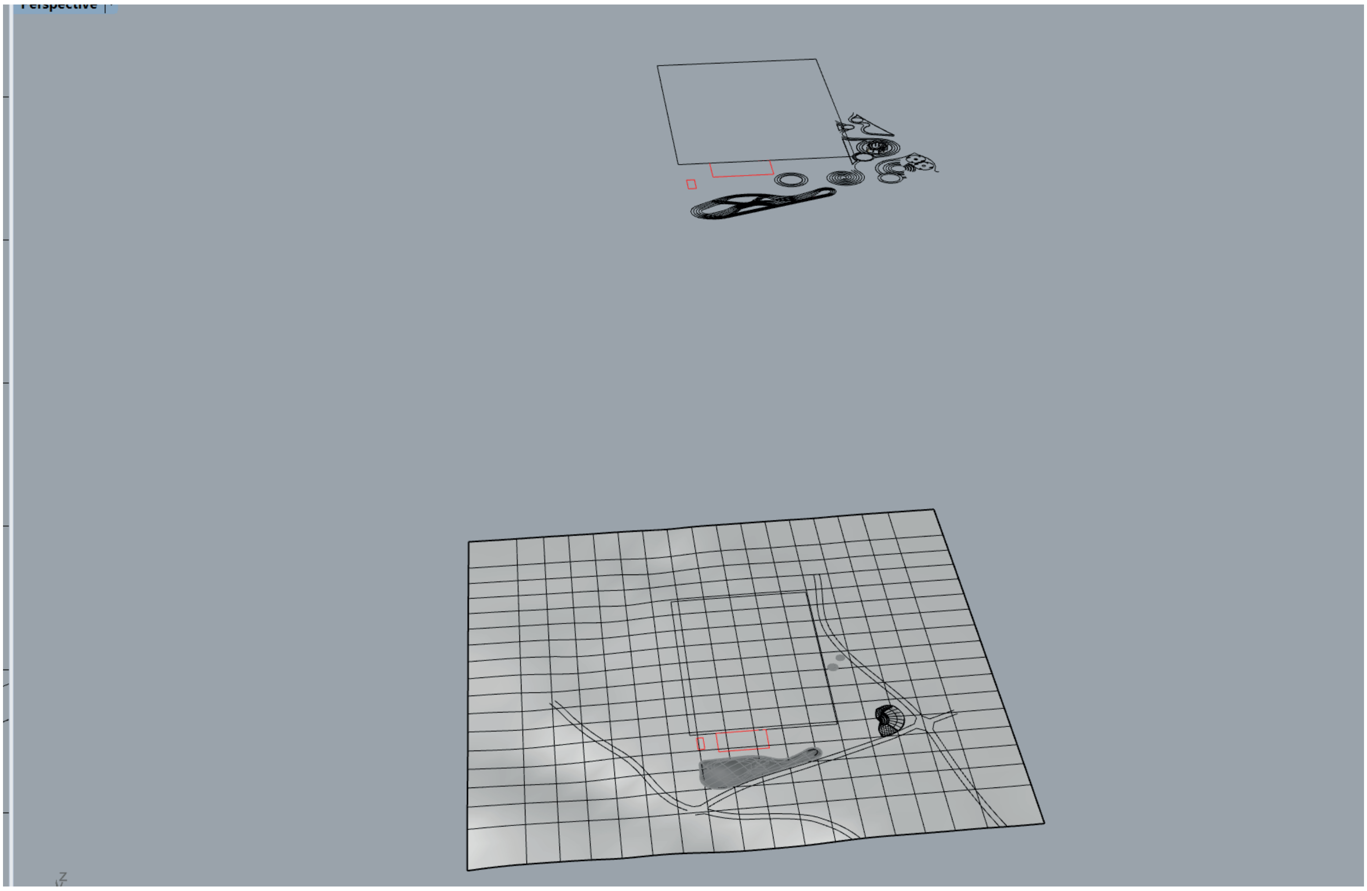
There was a problem with importing the other objects, as shown above. This was eventually resolved by opening the objects in Rhino and removing excess layers and saving back to DWG. However, not all materials are imported correctly.



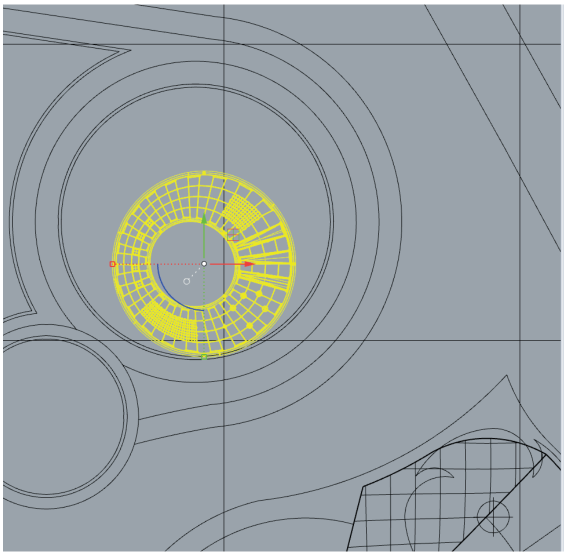
Above all the imported objects are shown on ground level.

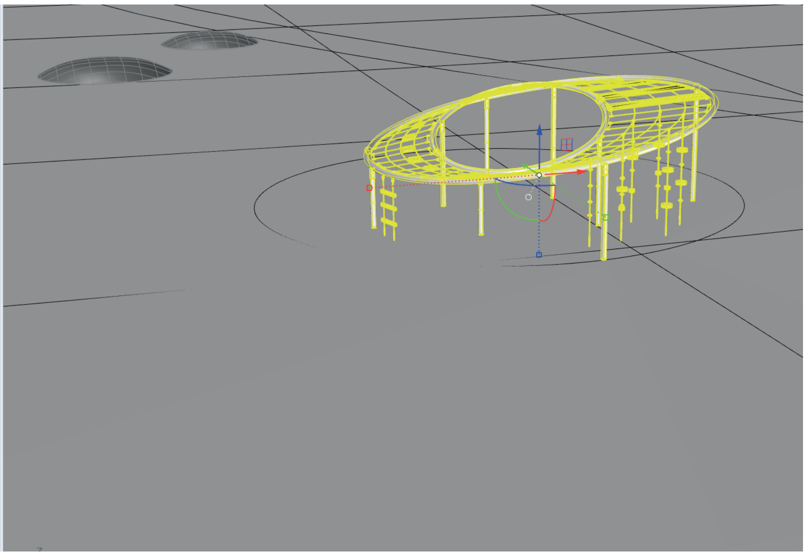
Rhino 3D:

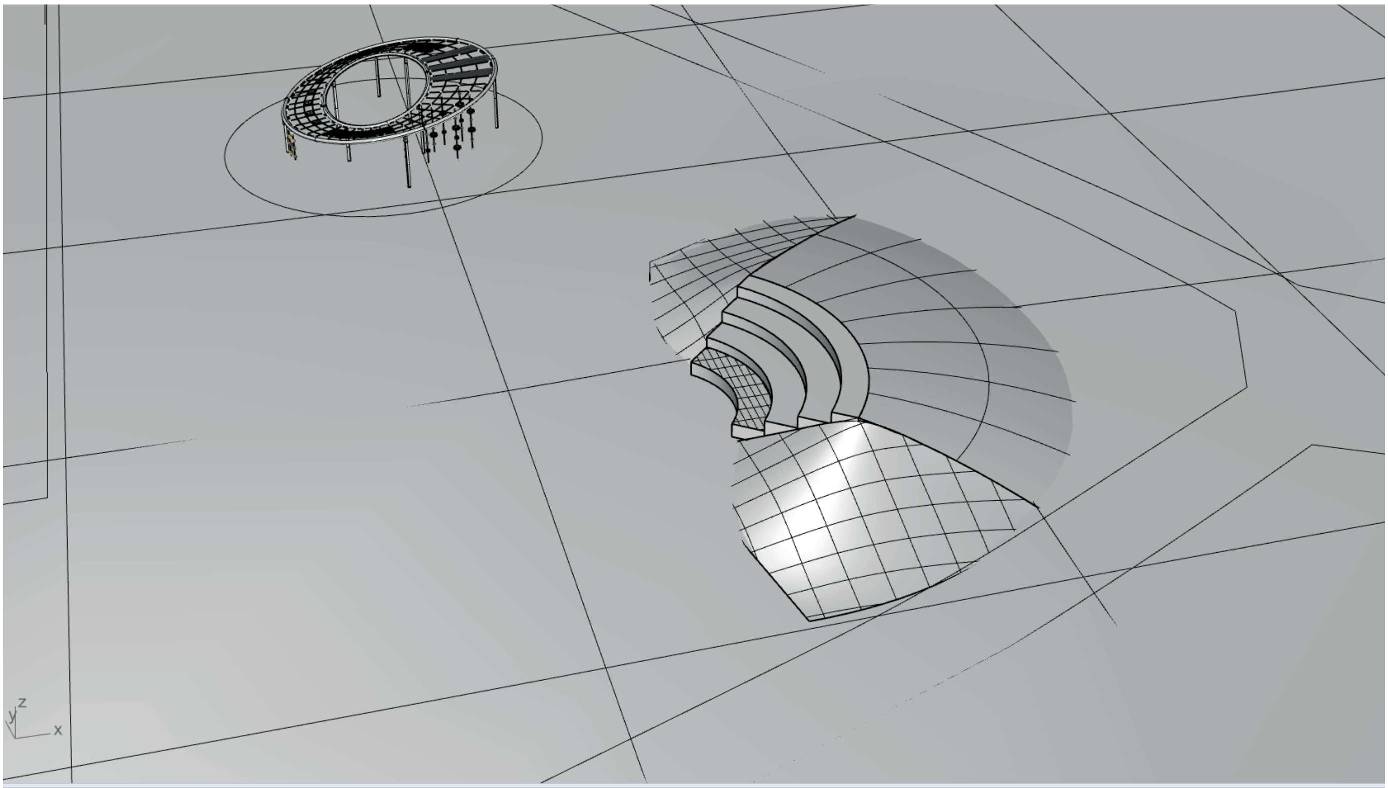
The CAD files can be imported and opened in Rhino without having to convert to another file format.



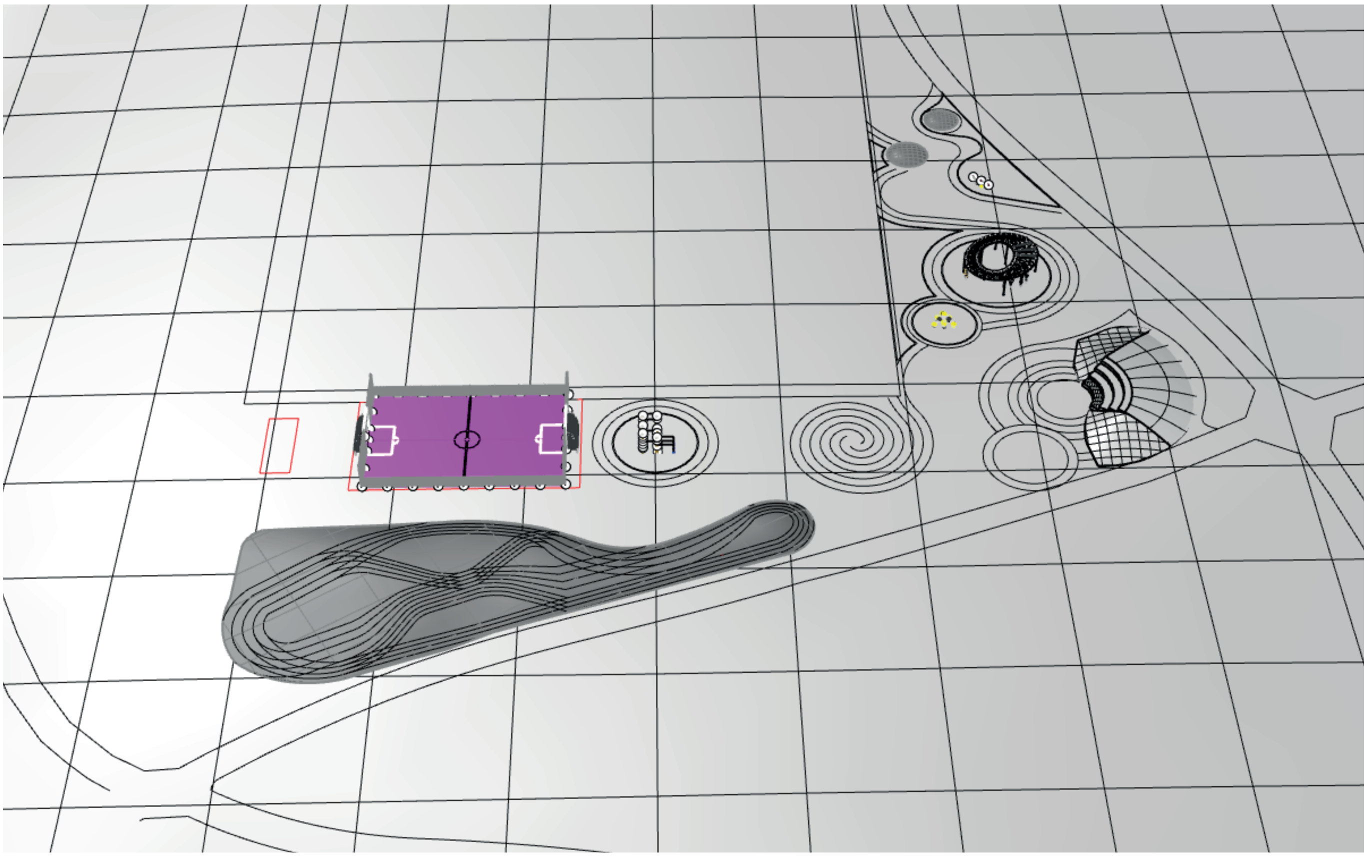
The plan is projected on the surface, depicted above, and this is used as reference for placing the objects. They have to be dragged into place manually, shown below.



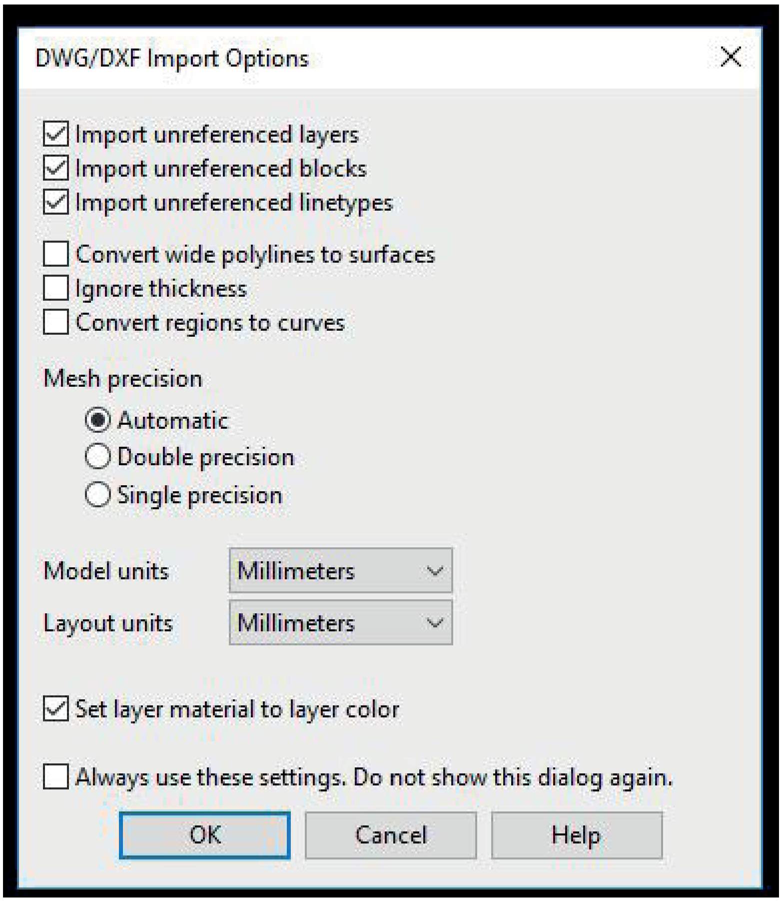




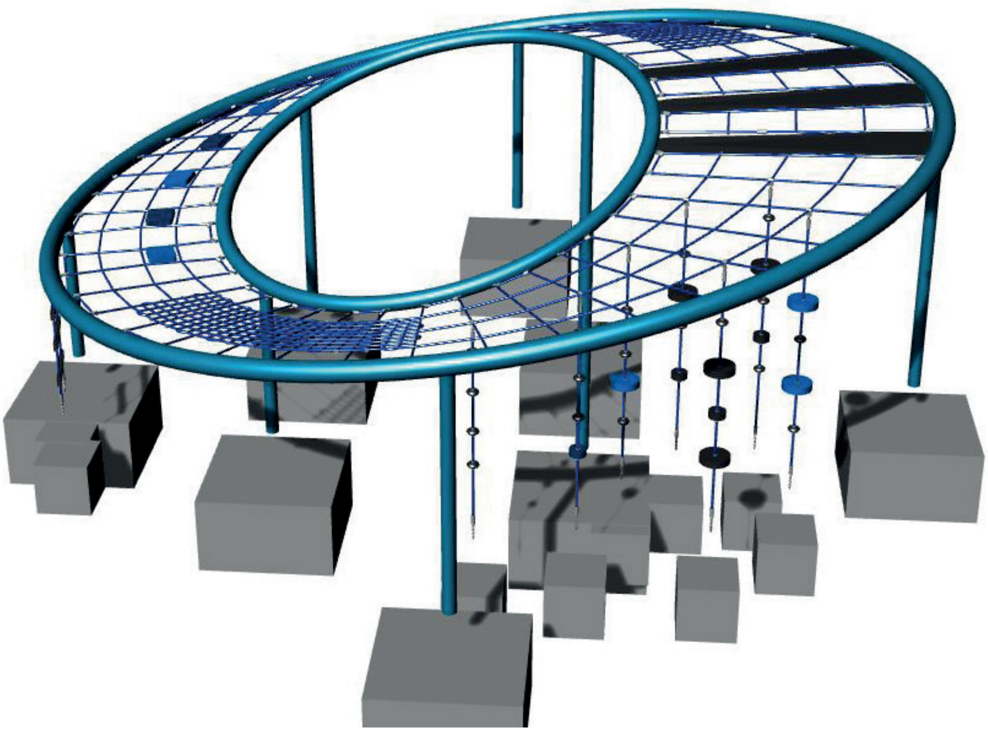
Mega frisbee shown in place above.



Other objects shown in place above.

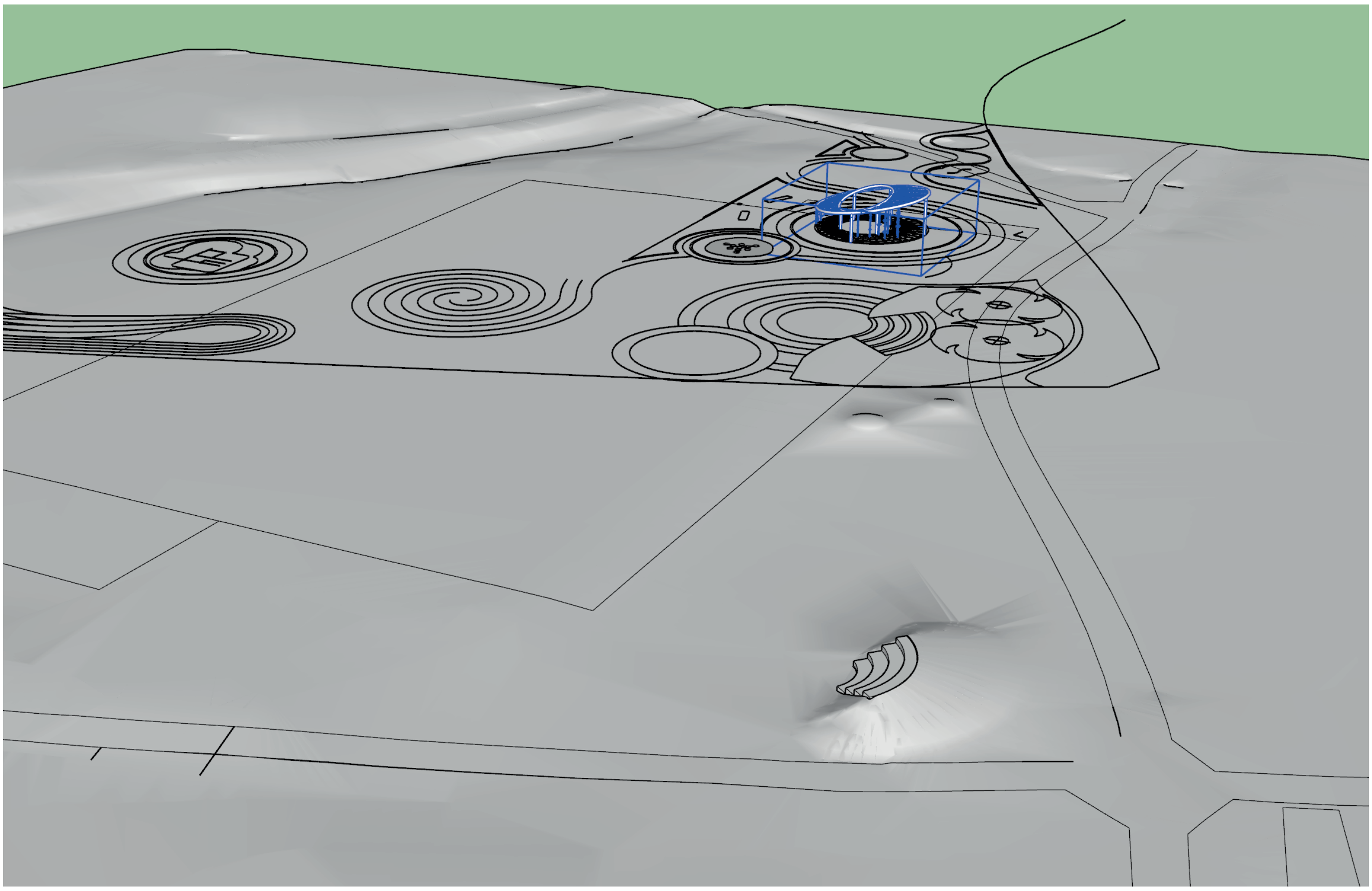


It can be ensured that the materials are imported by checking the box “Set layer material to layer color.”

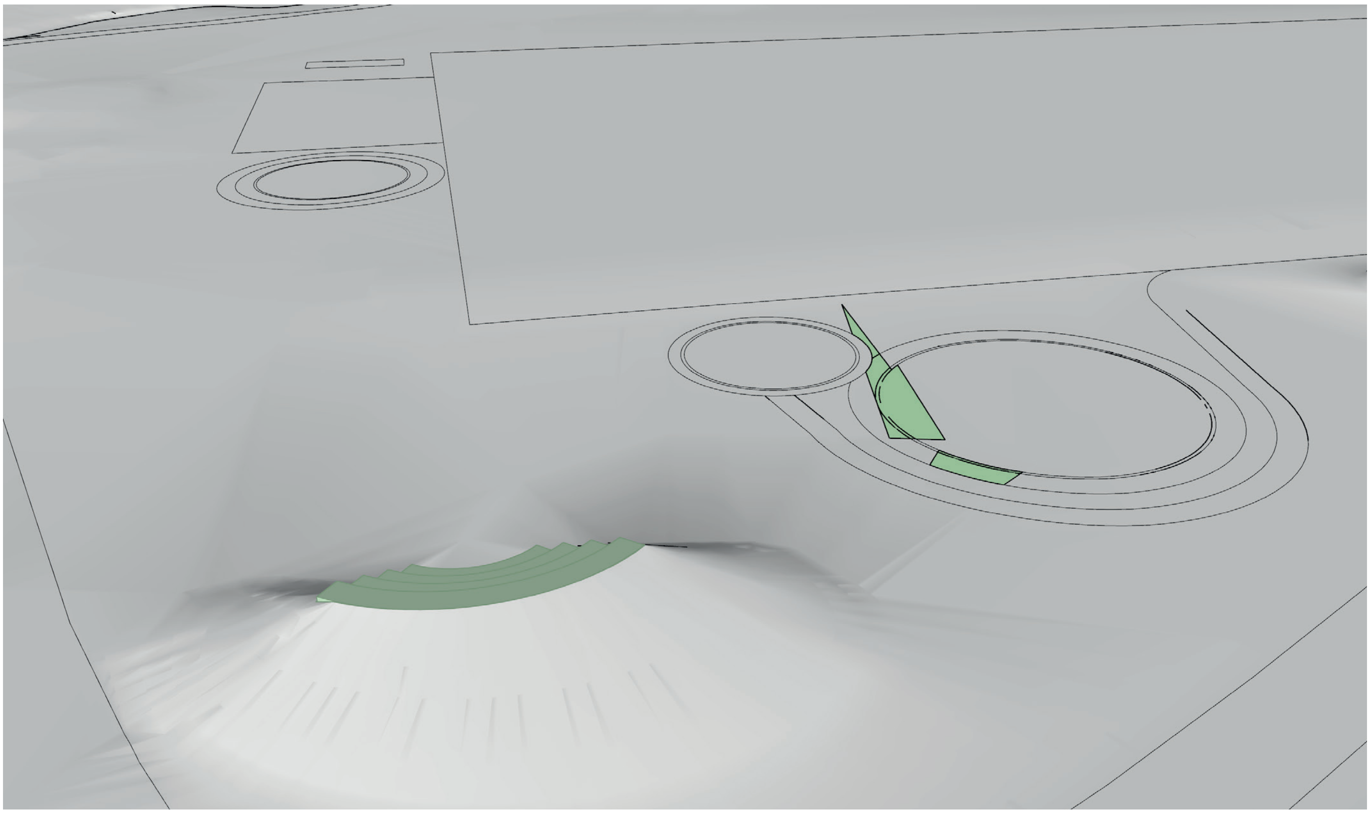


Sketchup:

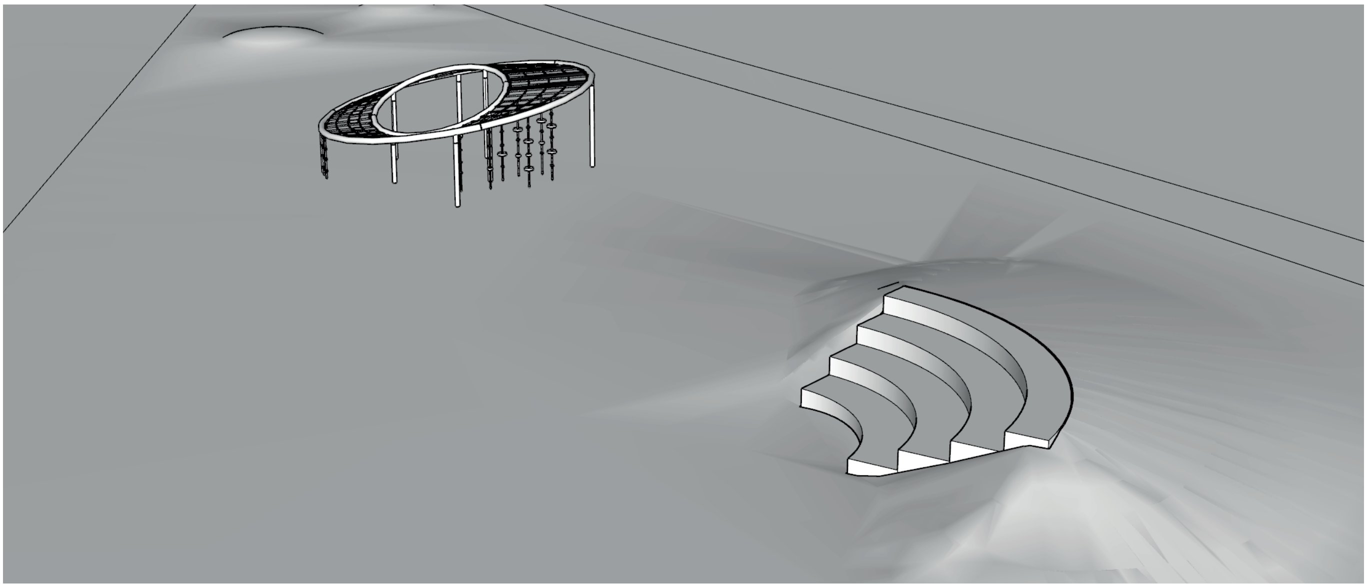
Sketchup can open the CAD files that were pre-cleaned for importing into Revit. The objects have to be dragged into place like in Rhino.



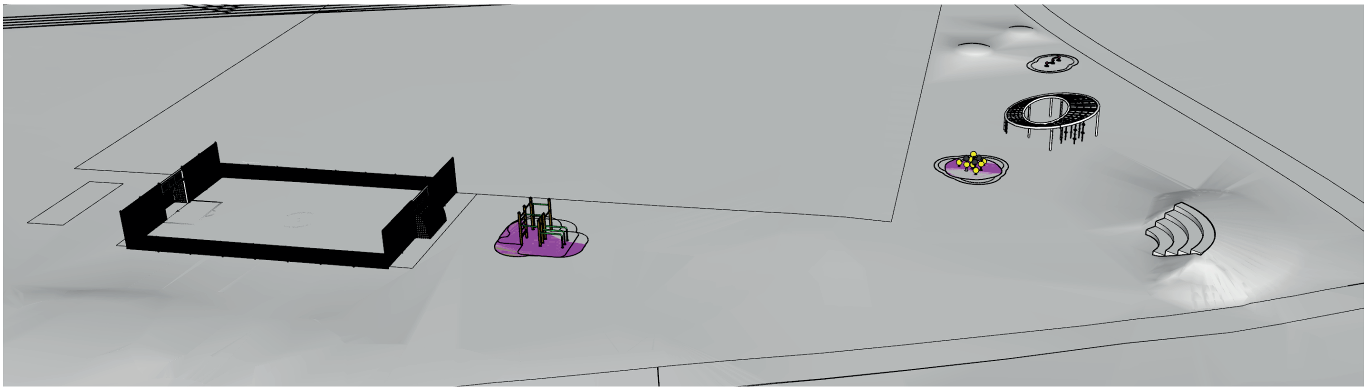
Above the mega frisbee is placed on the floating plan.



Attempting to project the plan on the terrain caused problems.



Instead the object was dragged vertically until Sketchup brought up the dialog " constrained on line intersecting plane", indicating that the object had met terrain surface.



The rest of the objects shown on terrain. Some objects’ materials were retained, but not all.

3.4. Verdicts

3. Other elements of landscape design	**Civil 3D**	**Infraworks**	**Revit**	**Rhino 3D**	**Sketchup Pro**
3.4. Playground equipment / street furniture	Opens CAD 3D models well. Materials retained. Object height can be input in properties as height from sea level.	Cannot use CAD format - another software must be used to convert the file. Materials not retained in this case. Object automatically placed on terrain.	Some problems with importing CAD files. Some materials retained. Object height can be input in properties as height from sea level. If families are used, can set on terrain automatically.	Opens CAD 3D models well. Materials can be retained if layer color matches layer material. Object must be dragged to correct level using guidelines.	Opens CAD models slowly. Most materials retained. Object must be dragged to correct level using guidelines.

3.5. Vegetation

Representing vegetation in 3D models is challenging due to their changing nature. Plants look different depending on season and trees keep growing throughout their lives. Normal 3D models can only represent a plant at one stage of its life. However, some professional plant libraries may include the ability to change the parameters of the plant to show it in a different stage of its life or in a different season. Some commercial plant libraries used in visualizations are SpeedTree and Laubwerk. In this evaluation, however, only free plant 3D models or those that come with the software package are used. These are not currently expected to have changeable parameters. How well the software can utilize the found 3D models is evaluated.

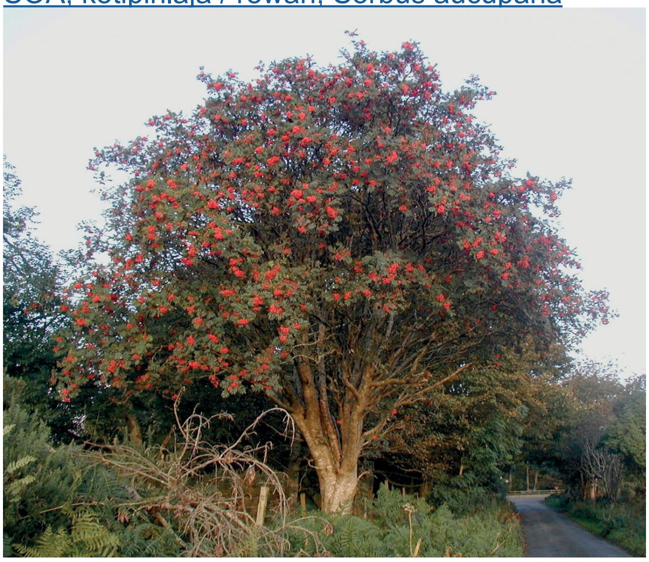
In this plan the following vegetation are used:

TREES

PSY, metsämänty / scots pine, Pinus sylvestris

https://commons.wikimedia.org/wiki/File:Pinus_sylvestris_p1.jpg

SOA, kotipihlaja / rowan, Sorbus aucuparia



By Eeno11 - Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=5029715

BUSHES

PmG, kääpiövuorimänty / dwarf mountainpine, Pinus mugo ‘Gnom’

https://www.hankkija.fi/Piha_ja_puutarha/kasvit/havukasvit/kaapiovuorimanty-mops-25-30-cm/

PoD, ‘Little Devil’ purppuraheisiangervo / common ninebark, Physocarpus opulifolius ‘Donna May Little Devil’

http://suomalainentaimi1.online.fi/purppuraheisiangervo

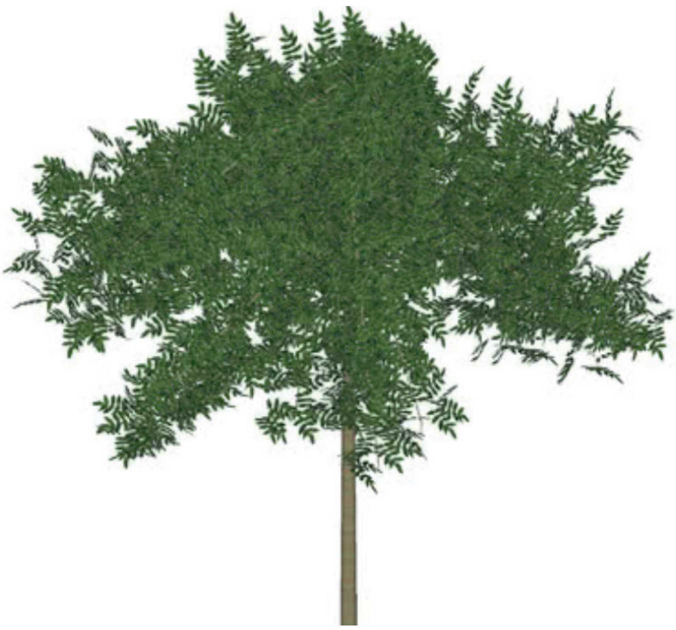
One difficulty with plant 3D models is that often the precise plant species cannot be found, so an approximately similar looking plant has to be substituted. In this experiment, the required vegetation will be searched for in the Sketchup Warehouse, as they can be used for free. It must be noted that either Sketchup or a software that is able to open the Sketchup file type is required - however, the basic version of Sketchup can be downloaded for free.

The most primitive vegetation models in Sketchup Warehouse are Face-2D objects - made with a texture on top of a 2D polygon, that is programmed in SketchUp to always face the viewer. Some more detailed 3D models are also available - these are useful for rendering accurate shadows. The 3D models found in Sketchup Warehouse are good examples of different levels of abstraction and detail in plant 3D models.

SCOTS PINE:

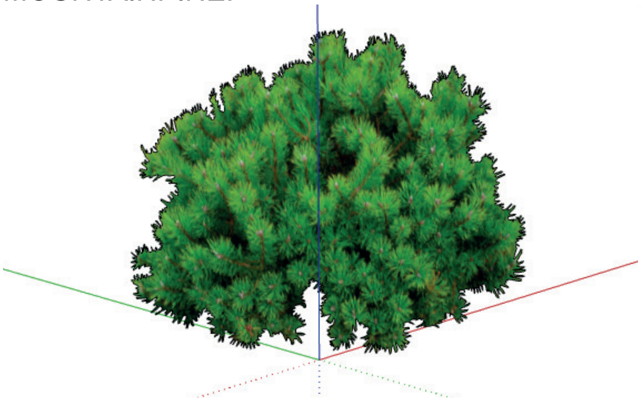
In Sketchup Warehouse different types of pine tree 3D models are found. The first one is a 2D face with the image of a tree as a texture. This can set to be a face-me object in Sketchup, so that it is always facing the viewer. The second one is two intersecting faces, so that the object can be viewed 3-dimensionally as an alternative to a 2D face-me object. The third one is a detailed 3D model of a small pine tree with leaves modeled as partly transparent textures.

ROWAN:



This is the only tree 3D model found of specifically a rowan in Sketchup Warehouse. It is a detailed 3D model that appears to have the individual leaves modeled with geometry instead of transparent textures.

MOUNTAINPINE:



NINEBARK:

Both of these bushes are 2D planes meant to be used as face-me objects in Sketchup.

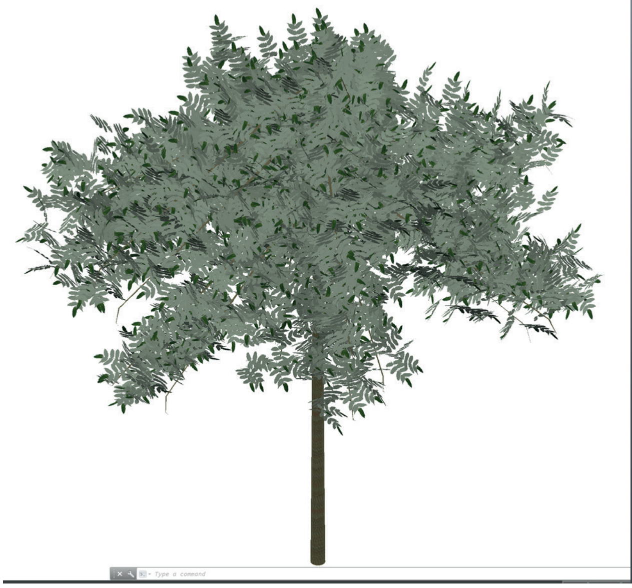
Another way to create a simple plant representation is to make primitive 3D shapes such as spheres or cubes that represent the plants. Often plants are photoshopped onto landscape archtecture images afterwards due to the difficulties of finding appropriate or accurate 3D models - in that case, simplified placeholder 3D models can be used. Simplified 3D models also have the benefit of better processing speed while 3D modeling - detailed tree models can be so heavy that they make the 3D model practically unusable. If they are to be used, they should be added last. Some professional plant library extensions include the option to view the same plant in either detailed or simplified mode because of this reason.

Because the number of plants in the design can be large, placing the models on terrain can be time-consuming. Automated processes would help with this task.

Civil 3D:

It is usually not necessary to include vegetation 3D models while designing in Civil 3D, since most of the work is done in plan view, 3D being used only . In this case, the detailed 3D models were found to be too heavy for Civil 3D to run smoothly.

This is how the 3D models imported in CAD format from Sketchup look like in Civil 3D:



The rowan tree imports rather well due to leaves being individually modelled. However, the leaves in the pine tree were made with a partly transparent texture instead of geometry. Exported into CAD form, the transparency does not work, and the leaves appear too bulky. Due to texture issues, the 2D bushes will not work as desired, either.

Infraworks:

Importing the rowan tree in FBX format into the Infraworks model poses problems - the loading time for the object is very slow and the textures do not appear. However, Infraworks has its own plant library included. These have textures and run smoothly. They can be used instead as placeholder plants in the 3D model.

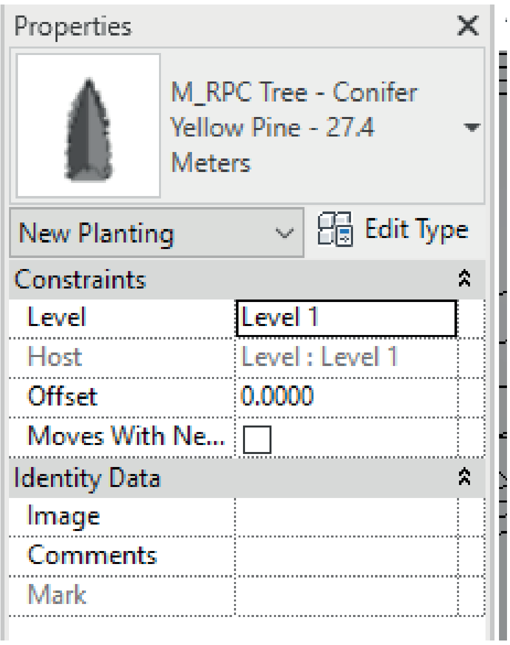
The textures of the pine tree face similar problems as the CAD version - the sections meant to be transparent do not appear transparent.

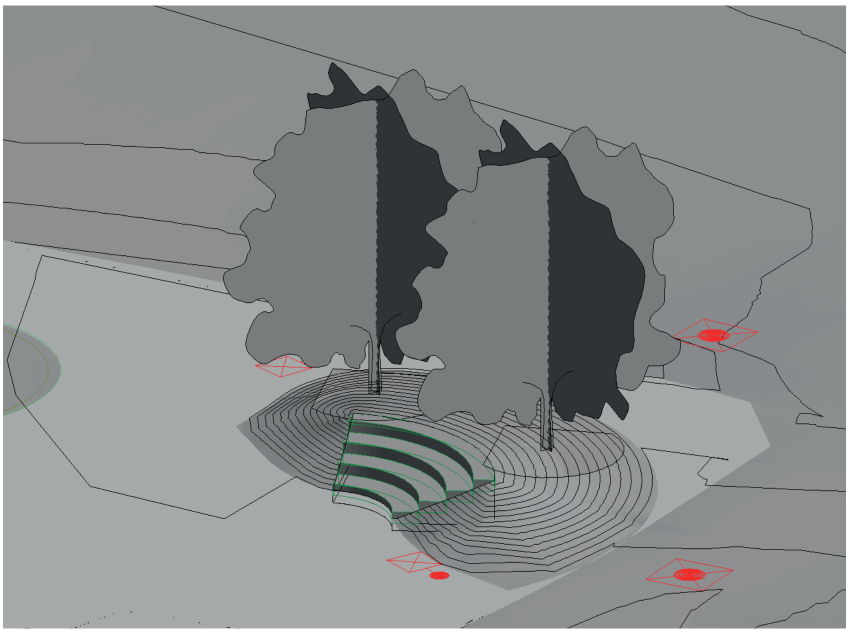
Revit:

The trees used in Revit must be in CAD format, since no other 3D model formats can be imported. However, these CAD files, when imported to Revit, do not appear as sophisticated as when opened in AutoCAD or Civil 3D. Adding the trees slows down the model considerably.

Revit also has planting "families" that can be used as trees. Note that these are only available if the families have been installed during installation of Revit. Families were not available on the university computer, so I completed this task using the families installed on my work computer.

These plants work well using Revit, and the model can be used smoothtly. The plants have a simplified tree model for standard viewing, as shown below. They must be placed as "Site Components" and will set on top of the toposurface automatically.

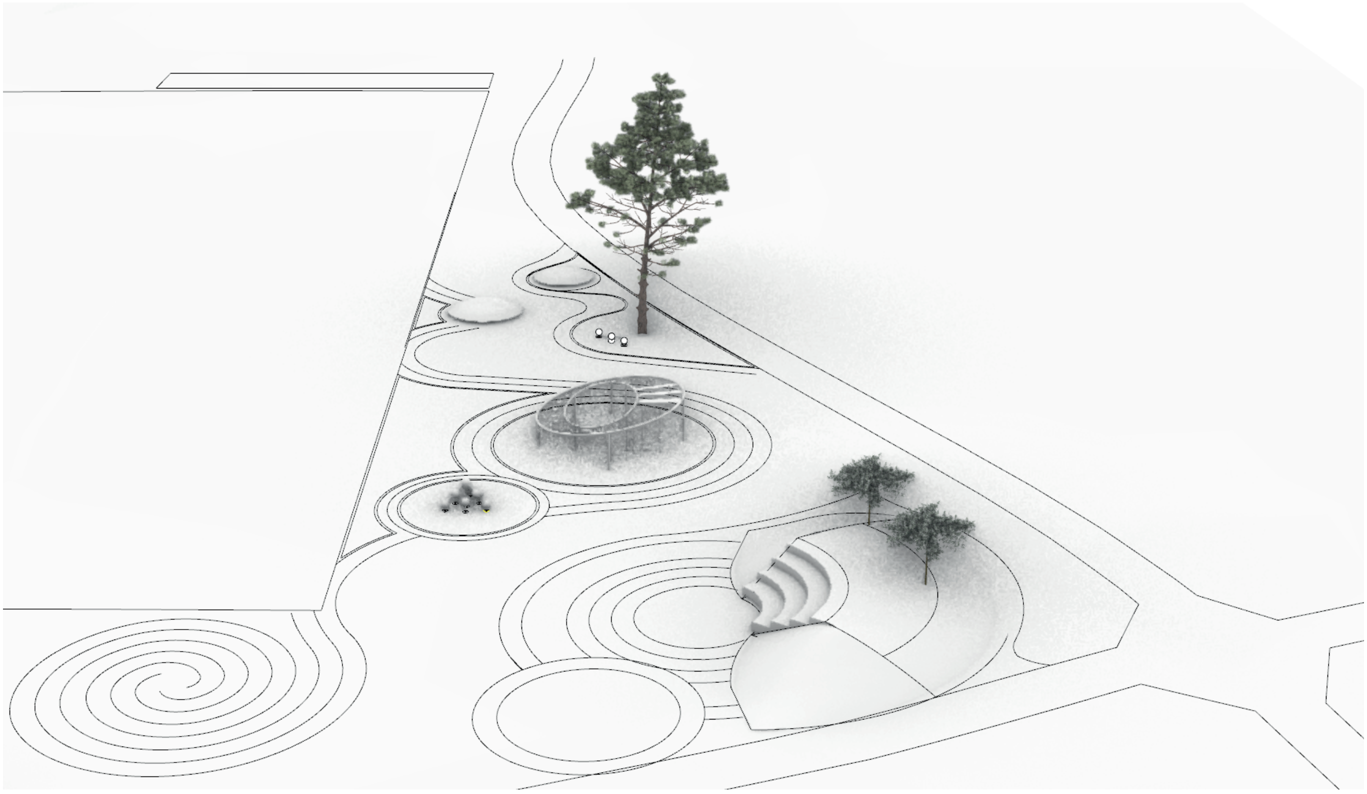




However, in realistic view, it is shown that the plants have a lot more detail when rendered.

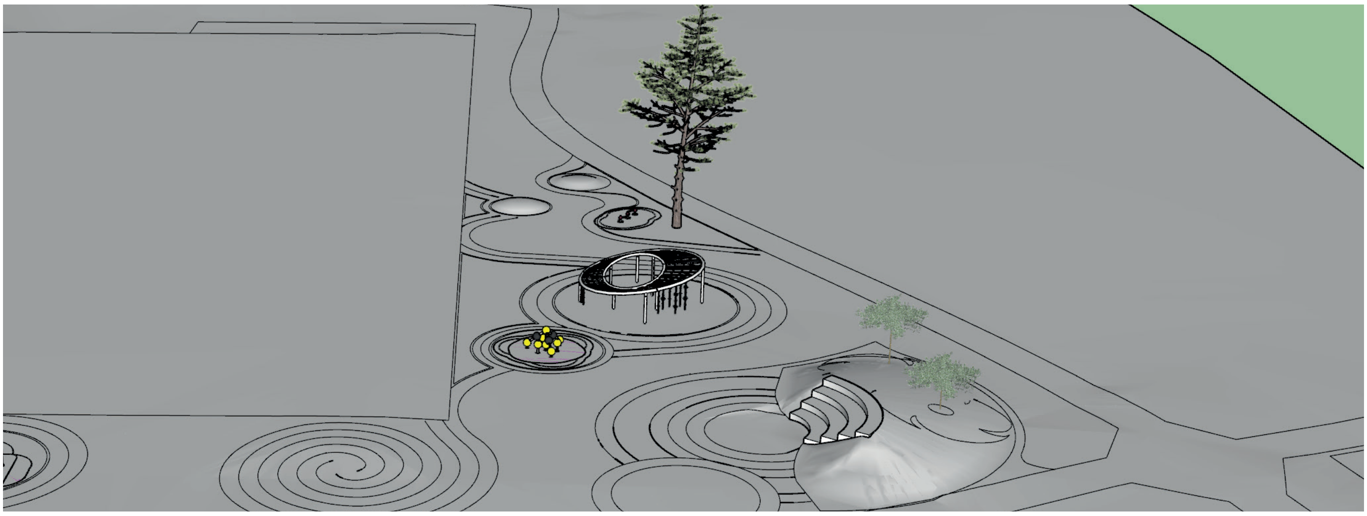
Rhino 3D:

The trees import well to Rhino 3D, since Rhino can open the Sketchup files directly without converting to another format first. This method retains the textures looking as intended. Rhino keeps running relatively smoothly after introducing the 3D models of the trees. However, with larger amounts of trees the model would get progressively slower.

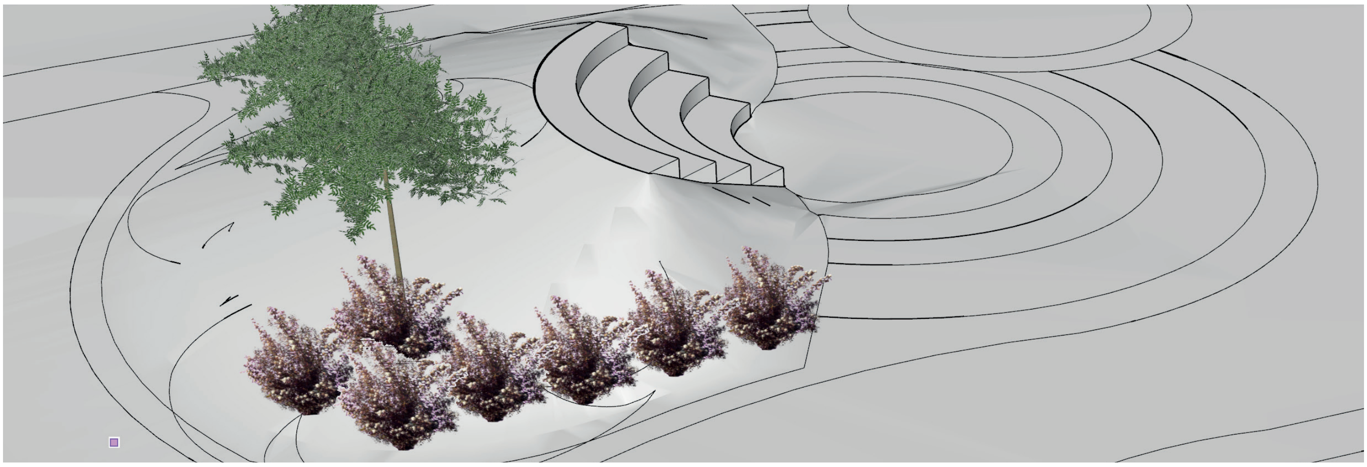


Sketchup:

The 3D models downloaded from Sketchup Warehouse will work best in Sketchup. However, together with the large terrain and complex sports equipment 3D models, adding the trees slows down the 3D model considerably.



The “2D face-me plants” work best when viewed on ground level or near ground level. It is also easy to make your own 2D plants with photos you have. Placing large amounts of plants on flat ground is easy with the array function - however, doing the same on a sloped surface can be tedious.



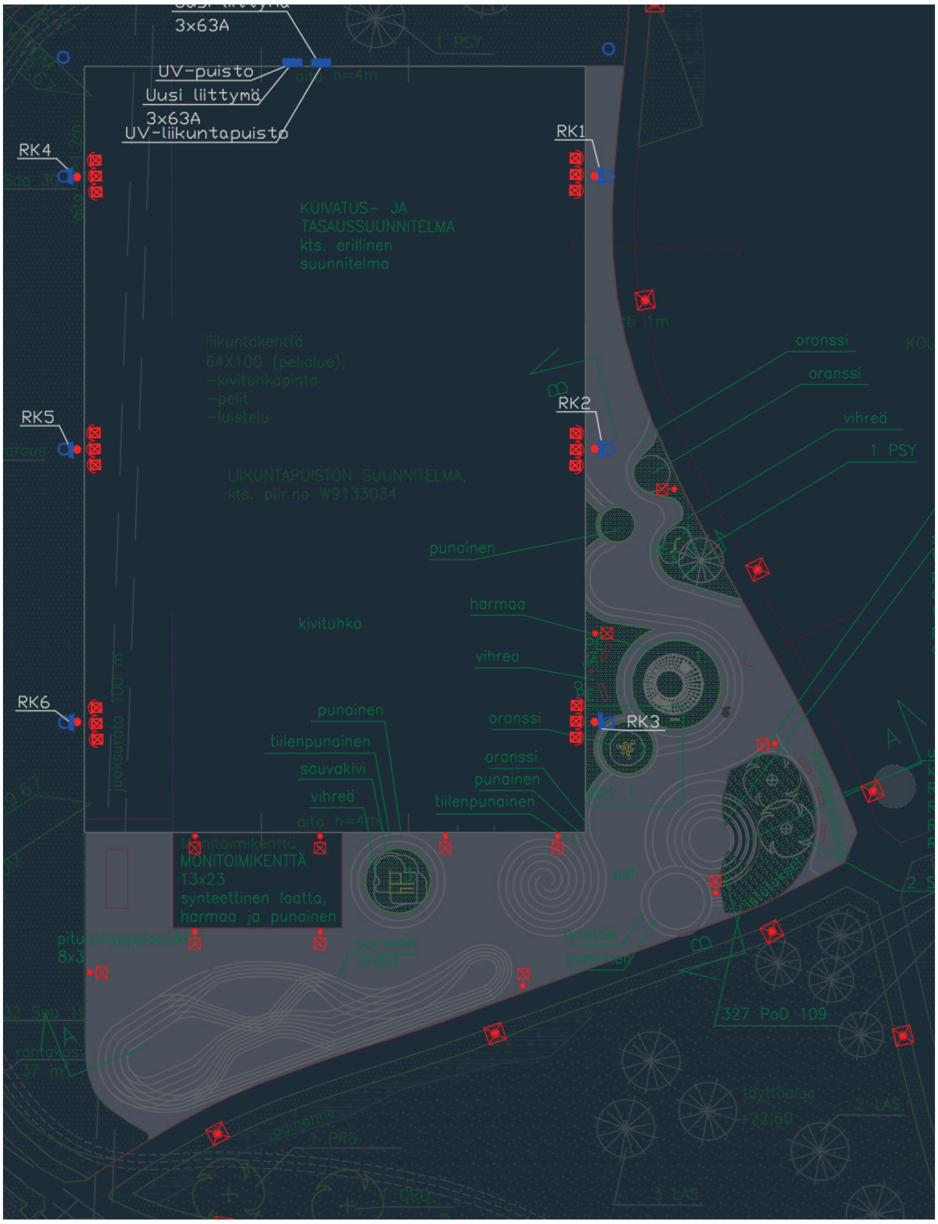
3.5. Verdicts

3. Other elements of landscape design	**Civil 3D**	**Infraworks**	**Revit**	**Rhino 3D**	**Sketchup Pro**
3.5. Vegetation	Only slight problems with importing trees. Detailed 3D models of trees are too heavy, causing the software to freeze.	Problems with importing trees. Includes own tree library. Runs smoothly.	Problems with importing trees. Detailed 3D models of trees are too heavy. Includes own tree library that runs smoothly.	No problems with importing trees. The software runs smoothly with a small amount of detailed tree models.	No problems with importing trees. Detailed 3D trees can be substituted with 2D face-me objects to make the software run smoothly.

3.6. Lighting

Landscape architecture offices usually make the initial draft of the lighting plan as part of the design. However in this project, at the construction design stage, the placing and typing of lighting was chosen by lighting designers.

Landscape architects usually make conceptual drawings to visualize the lighting - however, with proper rendering the proposed lighting could be visualized more accurately. In this comparison, the ability to render different lighting scenarios is considered.



MERKINTÖJEN SELITYKSET

1 Valaisin: PHILIPS, CitySoul Mini 2 gen, BPP530 T25 1 xLED35/740 DW, D9, RAL7009.

Pylväät 104-126, 129-250:
Sinkitty kartiopylväs 5m 2KL esim. Tehomet kartiopylväs A205SK.

Pylväät 301-302:
Sinkitty kartiopylväs 6m 2KL esim. Tehomet kartiopylväs A106SK.

2 Valaisin: esim. Valopaa VP1102 40 T4, DDF2 -liitäntälaitteella.

Pylväät: Tehomet hahmopylväät. (katso työselostus)

Jalustat: SJ-1.3 TER
Jalustat: SJ-1.3 TER 4KA

3 Pos. 3: esim. Philips CitySoul gen 2 Large BPP531 T35 1xGRN65/740 DM, D9, RAL 9007.

4 Pos 4: esim. Philips CitySoul gen 2 Large BPP531 T35 1xGRN65/740 A, RAL 9007.

5 Pos. 5: esim. Philips CitySoul gen 2 Large PHILIPS BPP531 T35 1xGRN55/740 A, D9, RAL 9007.

Pylväät P1-P12:
8m teräskartiopylväs 2KL esim. Tehomet B108S teräskartiopylväs

Jalusta: SJ-4/1500 TER. Yht.

6 Pos. 6: esim. Easy LED - Bubo B1 120-1400 UP-F 840, 514 W 46310lm.
Pylväät: Tehomet KH18TO15/89 orsi=1500mm.
Jalustat: SJL-5L.

7 Valaisin: iGuzzini iPro BX24 DALI WF 4000K, 41.6W 4395lm, väri: Grey 15.
Pylväs: 8m puupylväs 2KL esim. Tehomet Pallas street 2KL väri: Cinnamon.
Jalusta: esim. SJ-4/1500 TER.

8 Valaisin: Nightspot B LED Gobo-projektori.
Pylväs: 8m puupylväs 2KL esim. Tehomet Pallas street 2KL väri: Cinnamon.
Jalusta: esim. SJ-4/1500 TER.

9 Valaisin: Nightspot B LED Gobo-projektori.
Pylväs: 8m puupylväs 2KL esim. Tehomet Pallas street 2KL väri: Cinnamon.
Jalusta: esim. SJ-4/1500 TER.

N Nykyinen valaisinpylväs

P Purettava valaisin. Yhteiskäyttöpylväät säilytetään.

Liiketunnistin

Maadoituskupari Cu16 asennetaan kaapelikaivannon pohjalle.

HUOM! Kaikki valaisimet varustetaan valaisinkohtaisilla C2 Lumo -tarvikkeilla. Valonheittimien suuntaus tarkistetaan työmaalla.

HUOM! Kaikki pylväät tilataan valmiiksi rei'itettyinä.

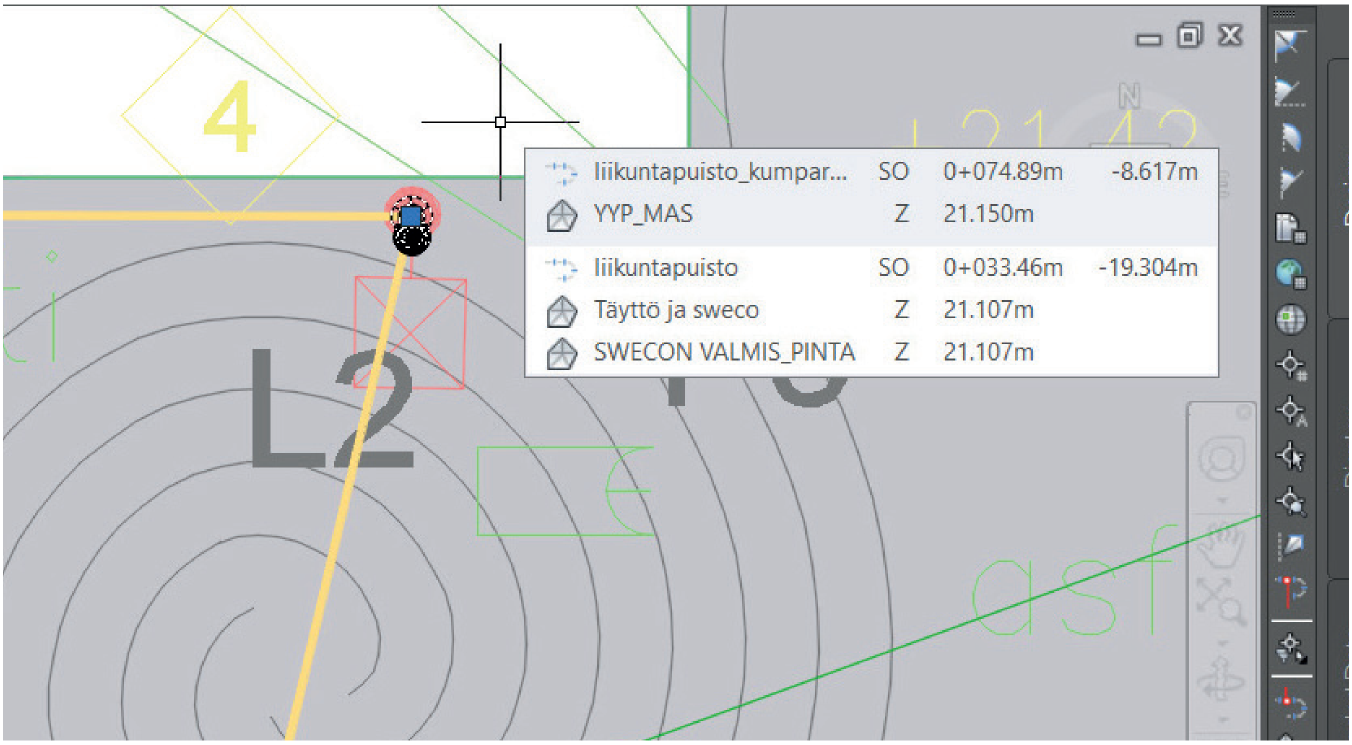
A Huom! Kaapelointi asennetaan B-luokan suojaputkeen.
Teiden alituksissa ja liikennealueilla A-luokka.
Varoitusnauha asennetaan kaapelin yläpuolelle maahan
n. 20cm syvyyteen valmiista maanpinnasta.

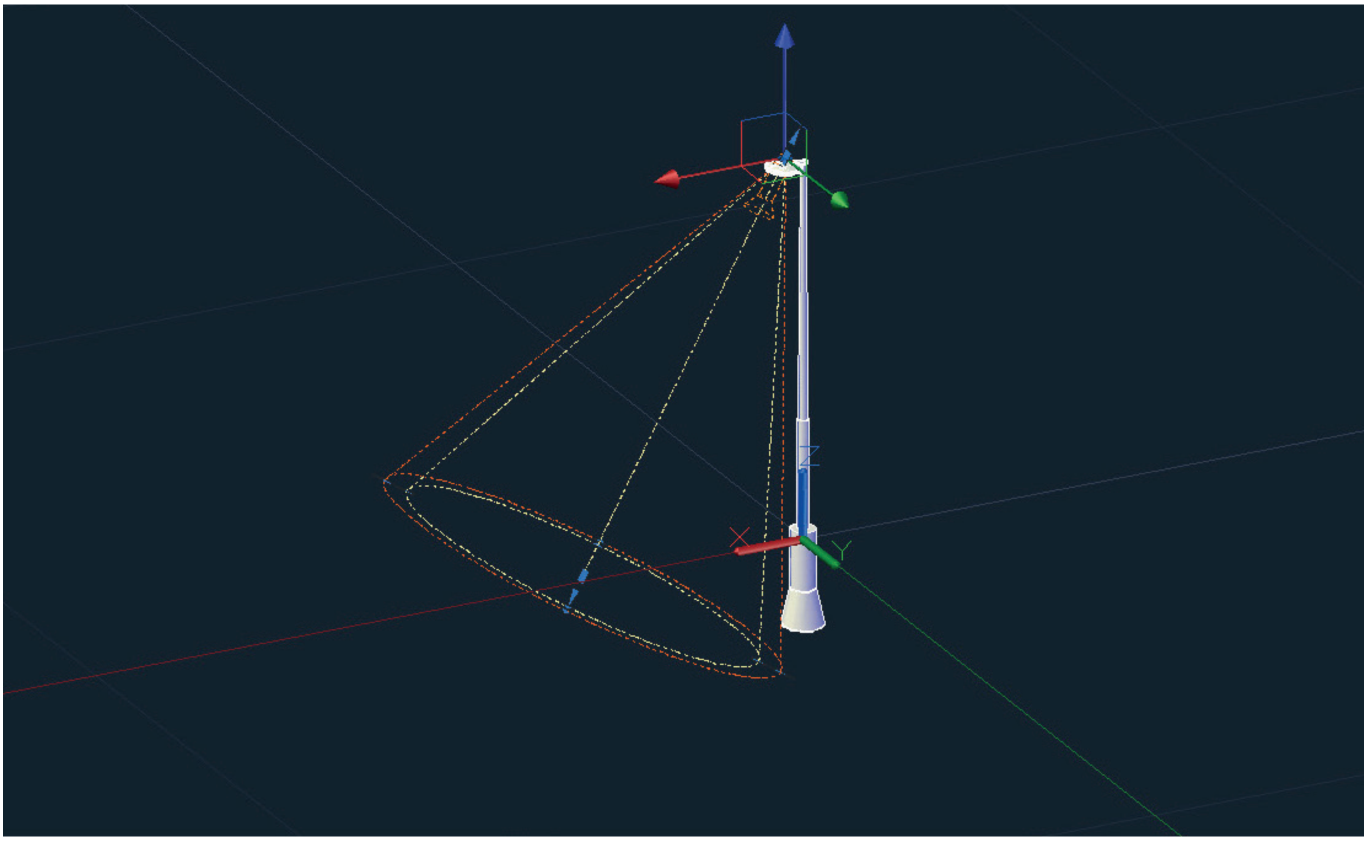
Aluekaapelointi maakaapelilla.

The following 3D model of the lighting poles was found. It is in DWG form.

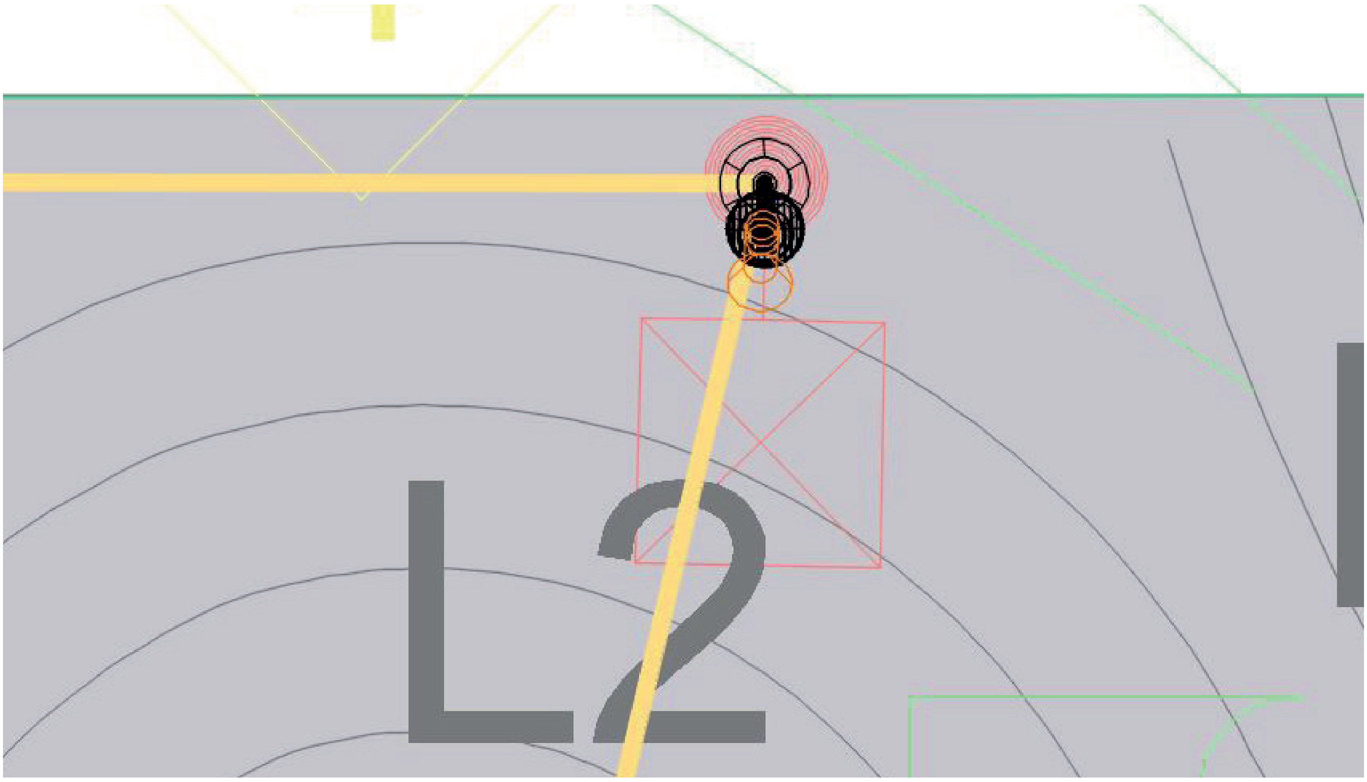
Civil 3D:

It is possible to place the 3D model in Civil 3D like the other furniture evaluated above. Here it is placed as a block, so that the model definition can be updated afterwards. Below the light object is shown located on the correct height level as measured from the terrain surface.





Above a spotlight object is added to the existing model definition, so that the lighting pole will actually provide light in a rendering. The image below shows that it has been updated to the plan drawing as well. The red icon that looks like a flashlight indicates a spotlight.

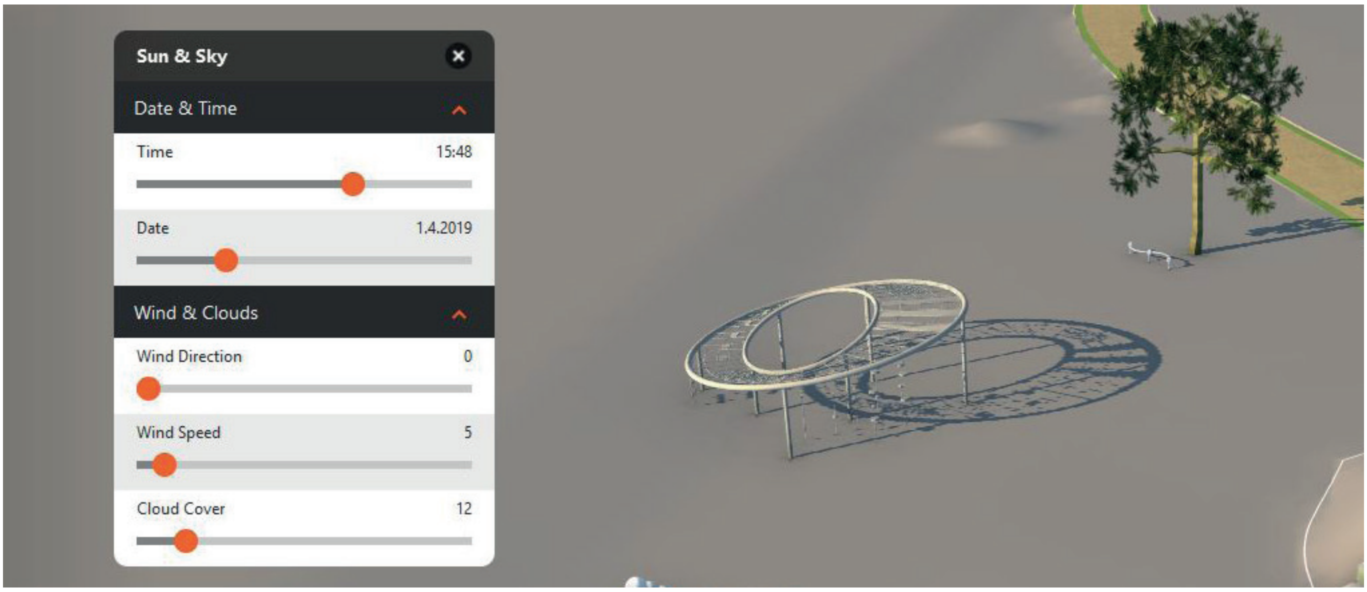


The complexity of the model is causing performance issues, so no more light poles are placed. While placing a lighting pole, the software lags too much.

The sun can also be placed as a directional light.

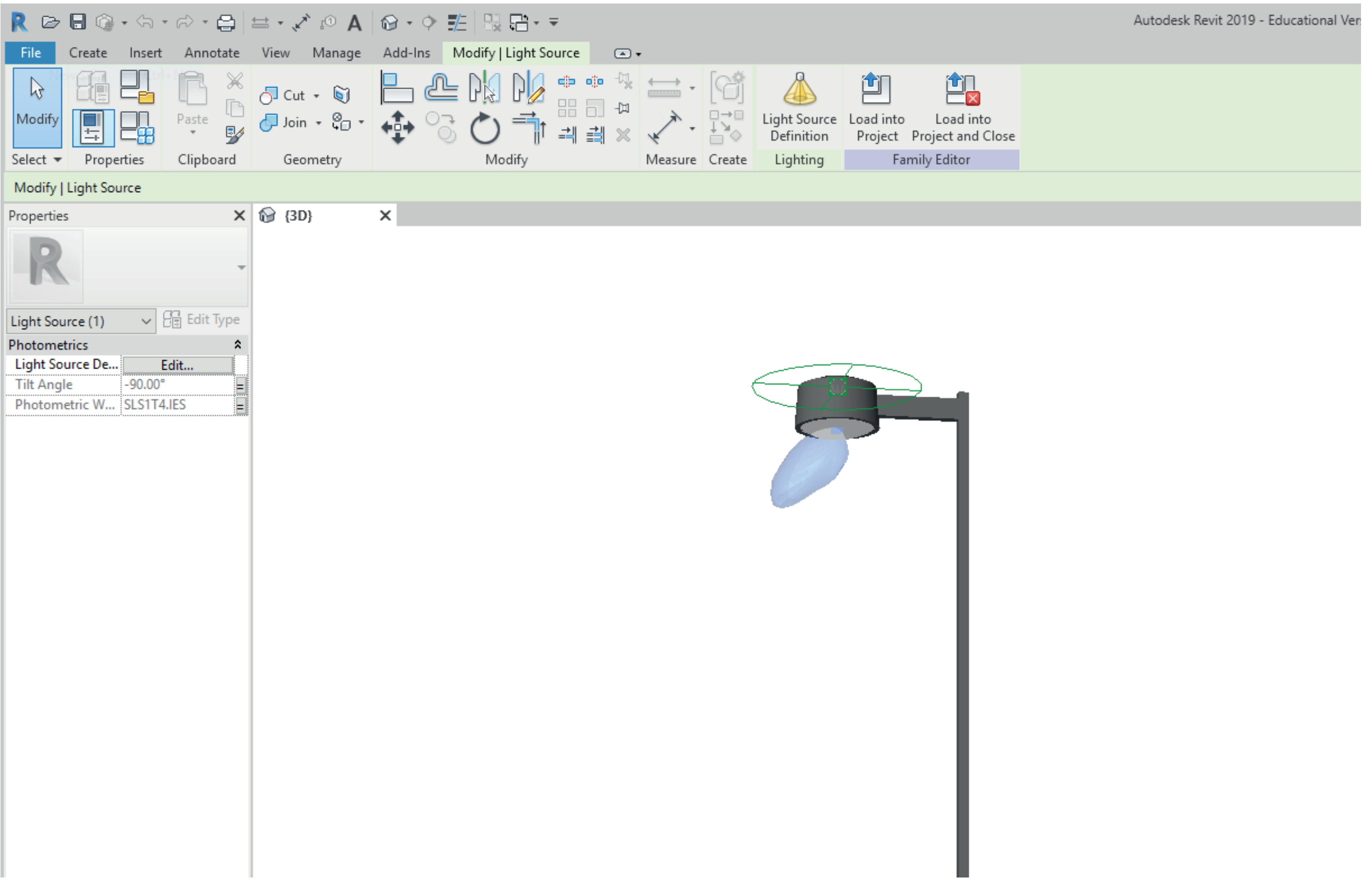
Infraworks:

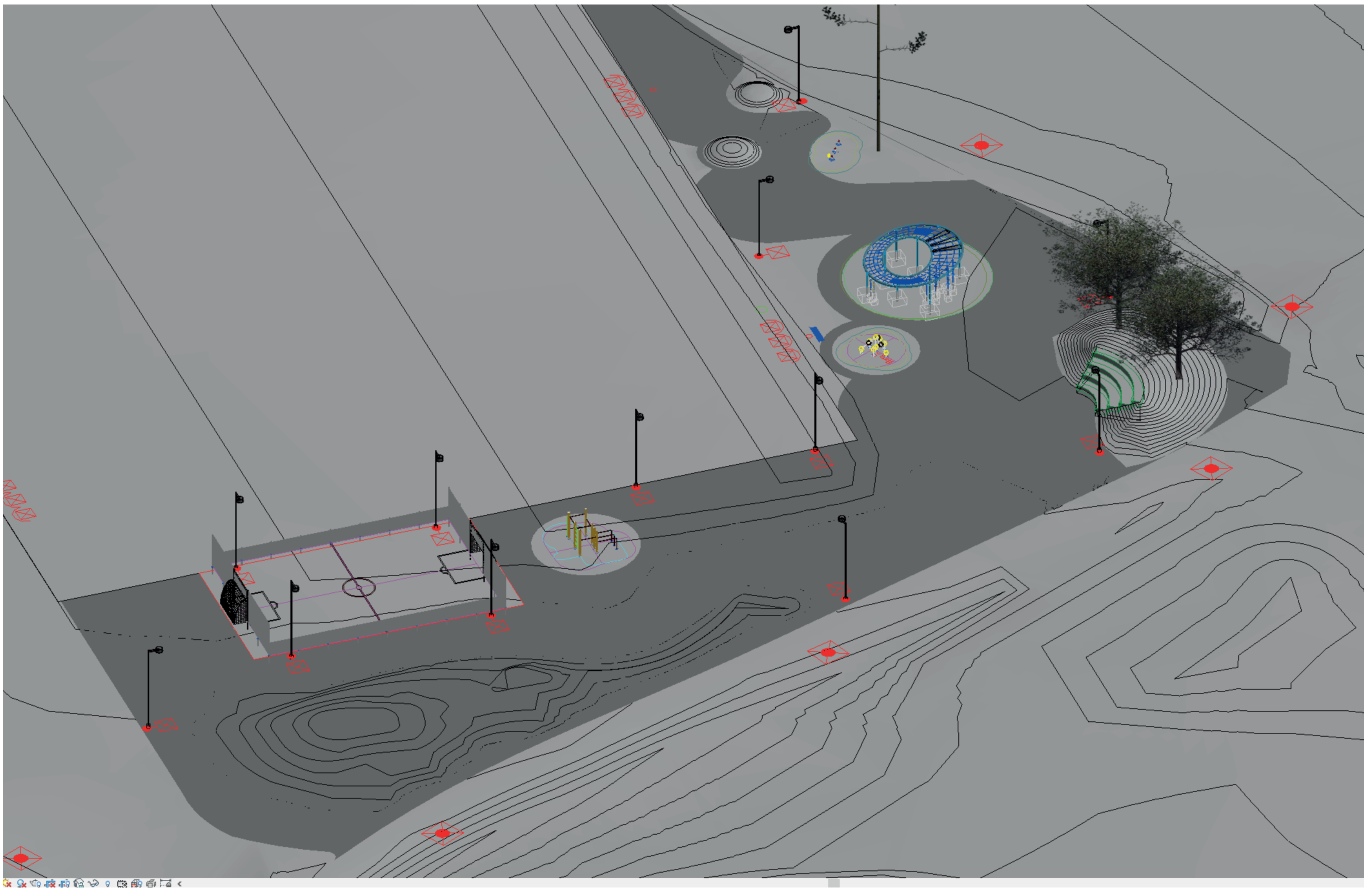
The light poles could be placed as objects, but the lights themselves cannot. The only light used in Infraworks is the sunlight. The sun settings are shown below.



Revit:

Revit families contain a lighting pole that has a functional light placed inside it, as shown below. A new family with the specific light pole could be created as well.

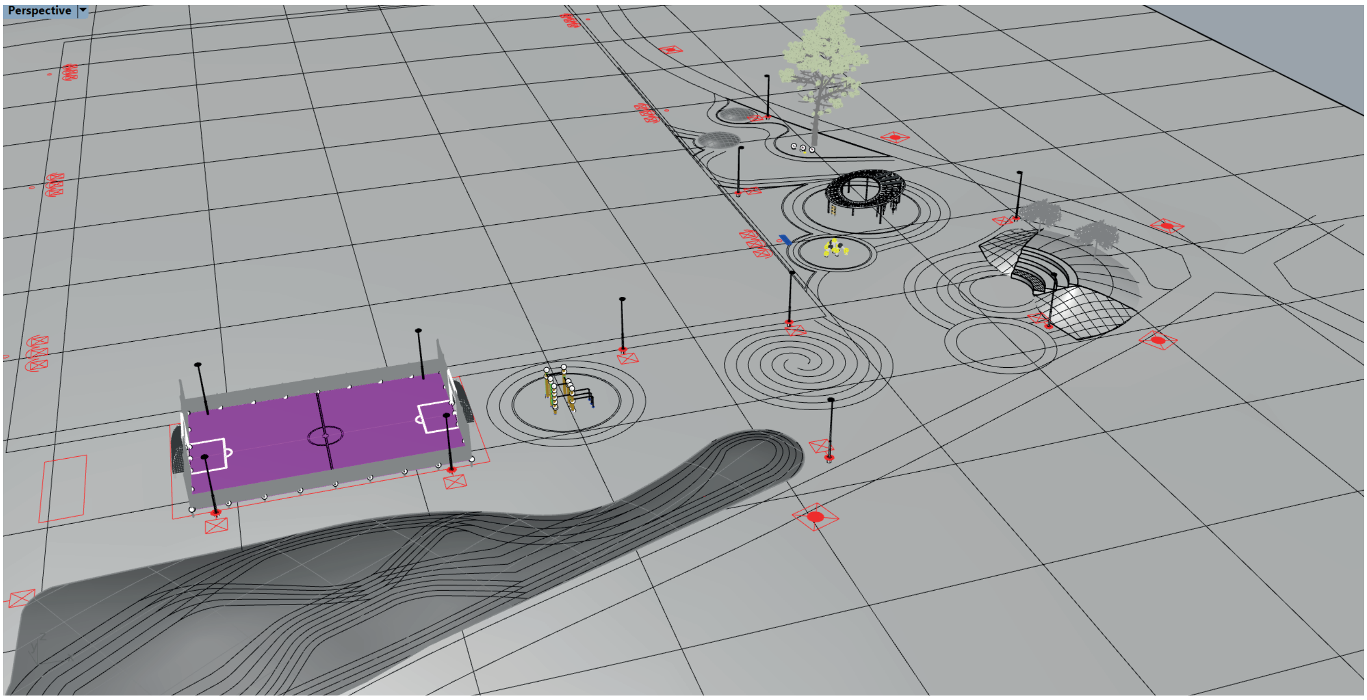


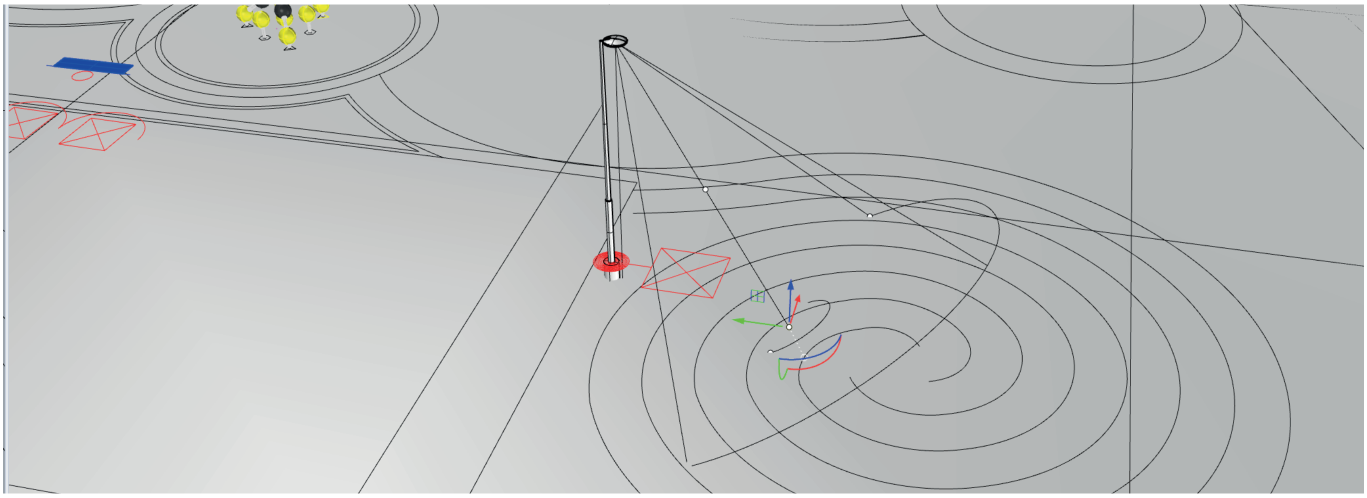


The light pole can be easily placed on the plan - automatically setting itself on the toposurface. Above are shown the light poles.

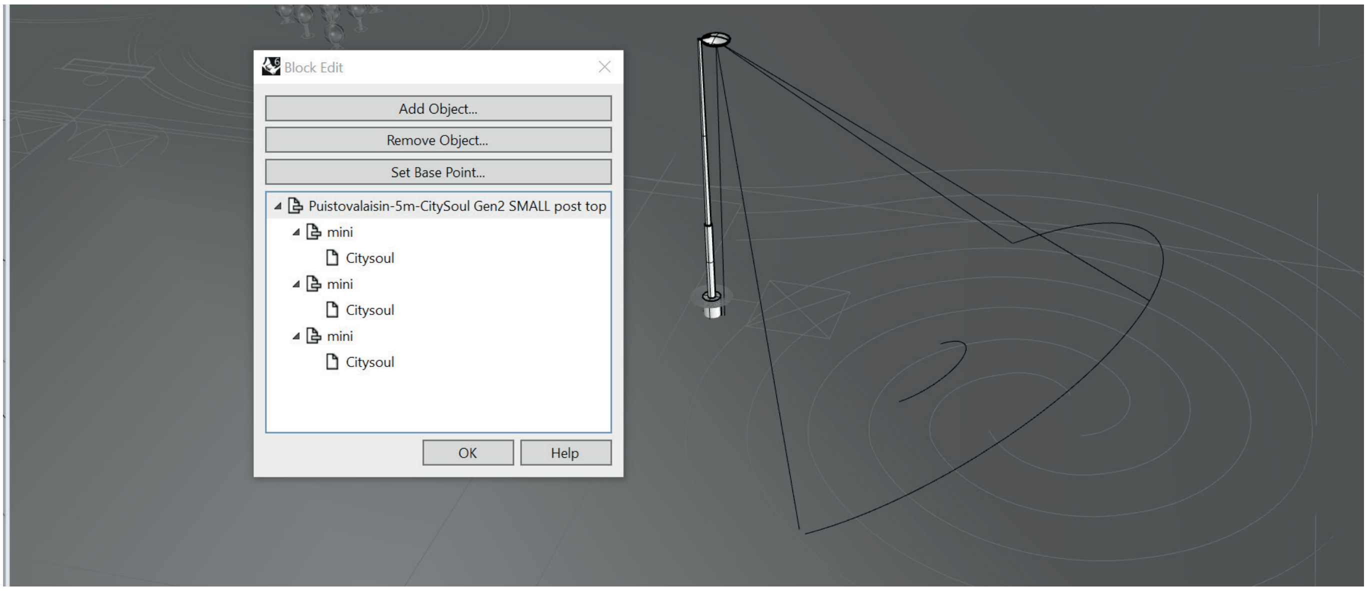
Rhino 3D:

In the below image, the lighting poles are set in place as blocks.

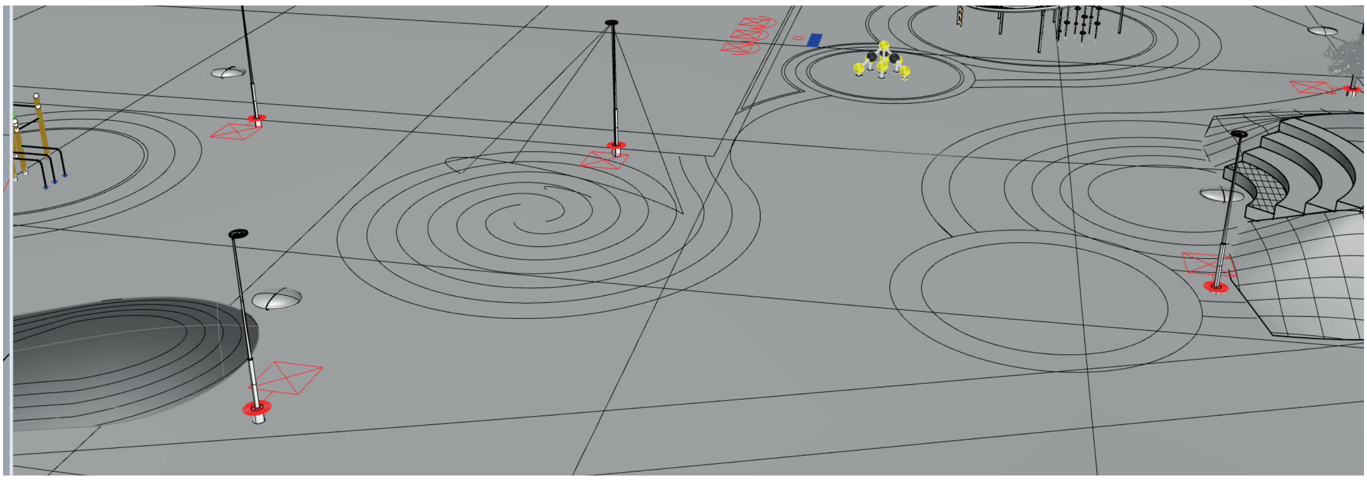




Next, a spotlight is added to the light pole, as shown above. The idea is to update the block so that the spotlight is added to every light pole already placed.



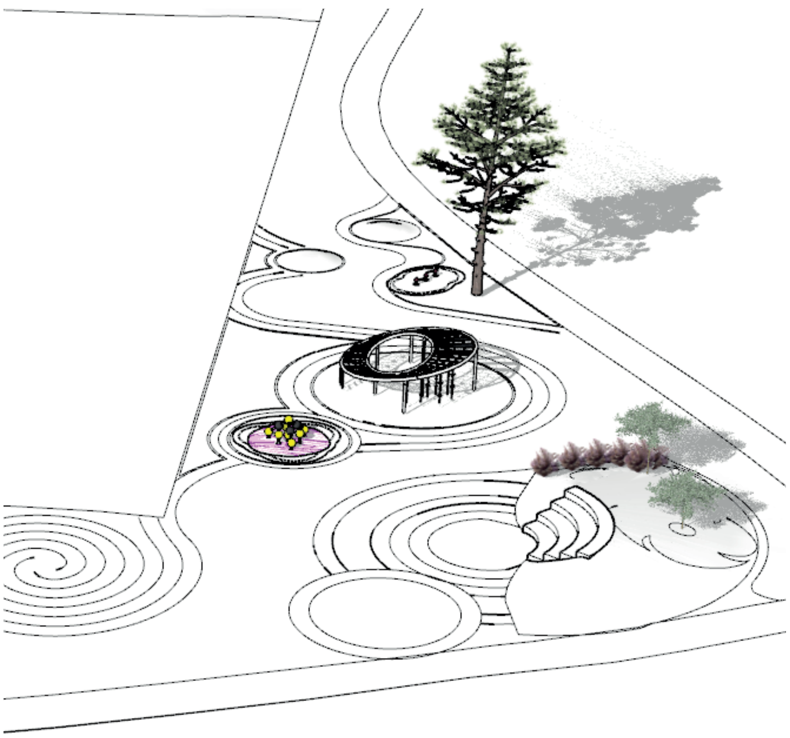
However, adding the spotlight to the block does not create the desired results, because light objects cannot be contained inside blocks in Rhino. Below it is shown that adding another geometric object, a floating disc, does work. That means the problem is the light object.

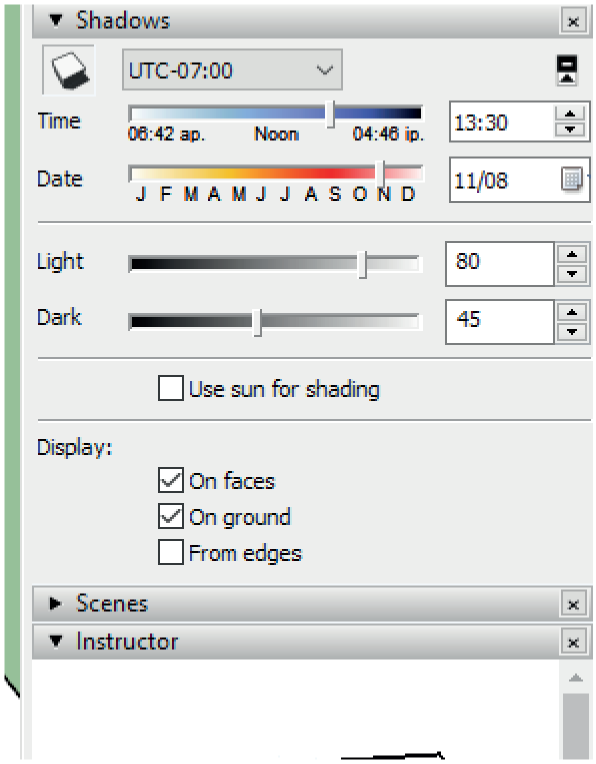


It would be possible to copy the light with the pole to every desired location instead, but having already placed all the poles, this would mean extra work.

Sketchup:

The lighting poles can be placed in the model as 3D objects. However, the only light source native to Sketchup is the sun.



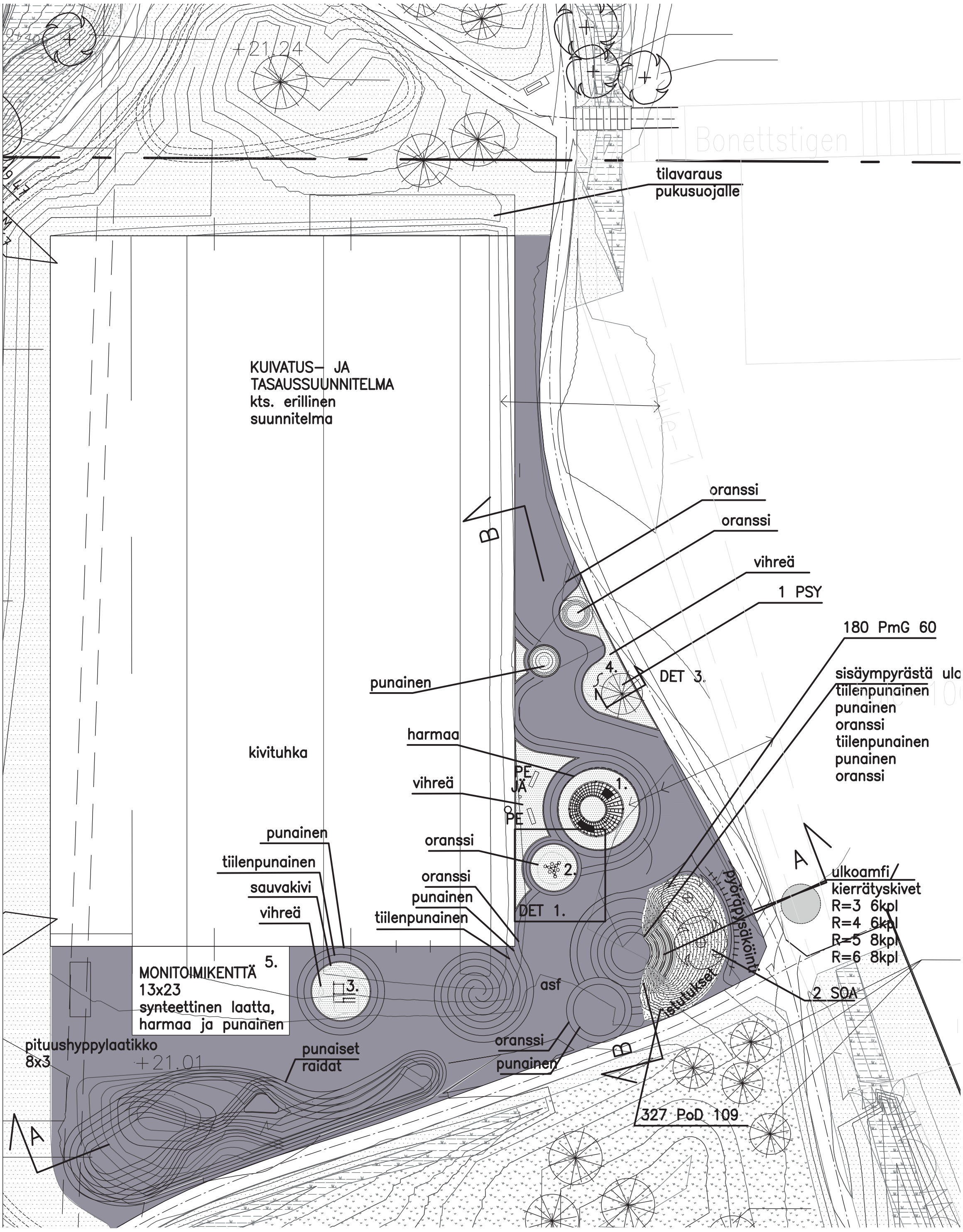


3.6. Verdicts

3. Other elements of land-scape design	Civil 3D	Infraworks	Revit	Rhino 3D	Sketchup Pro
3.6. Light-ing	Sunlight. Streetlights can be created with a 3D model and a spotlght. Moving streetlights is unacceptably slow due to the amount of detail in the model.	Sunlight. No spot-lights.	Sunlight. Revit light family contains a street light that in-cludes a spot-light.	Sunlight. Streetlights can be creat-ed with a 3D model and a spotlght. However, spotlights cannot be placed inside a block, which would make duplicating the street light easier.	Sunlight. No spot-lights.

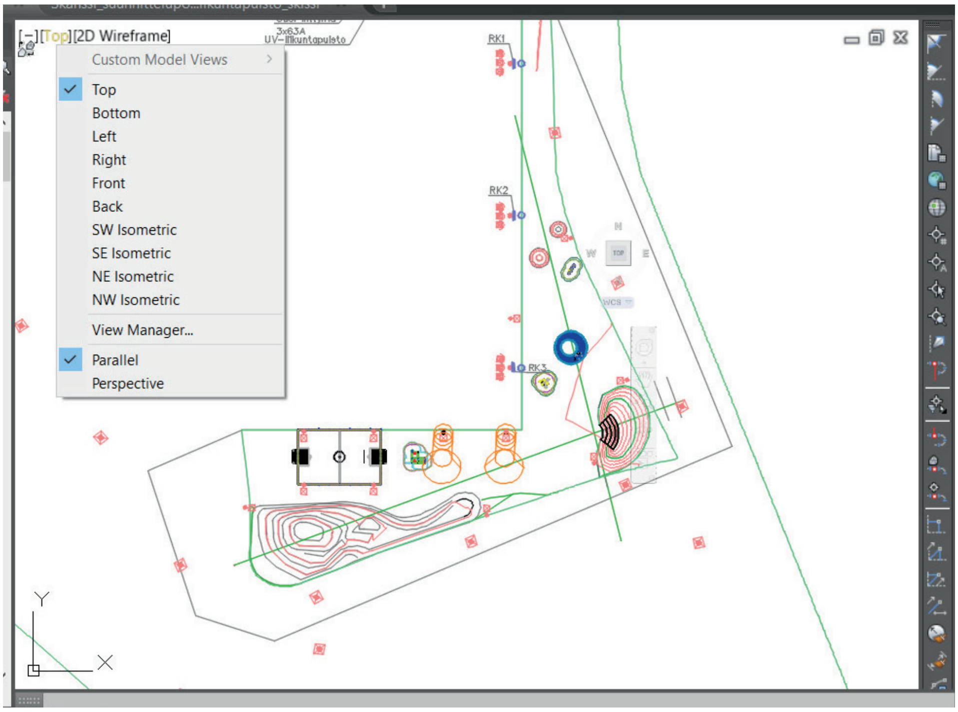
4.1. Site plan

Usually a landscape architecture 3D model is done by first creating a site plan, and then using that to create the 3D model. However, it may be done in reverse in a model-based design process. In this case, the site plan was created first using AutoCAD Map 3D. However, a ground plan will also be made using the 3D model for demonstration purposes. This is the original site plan:

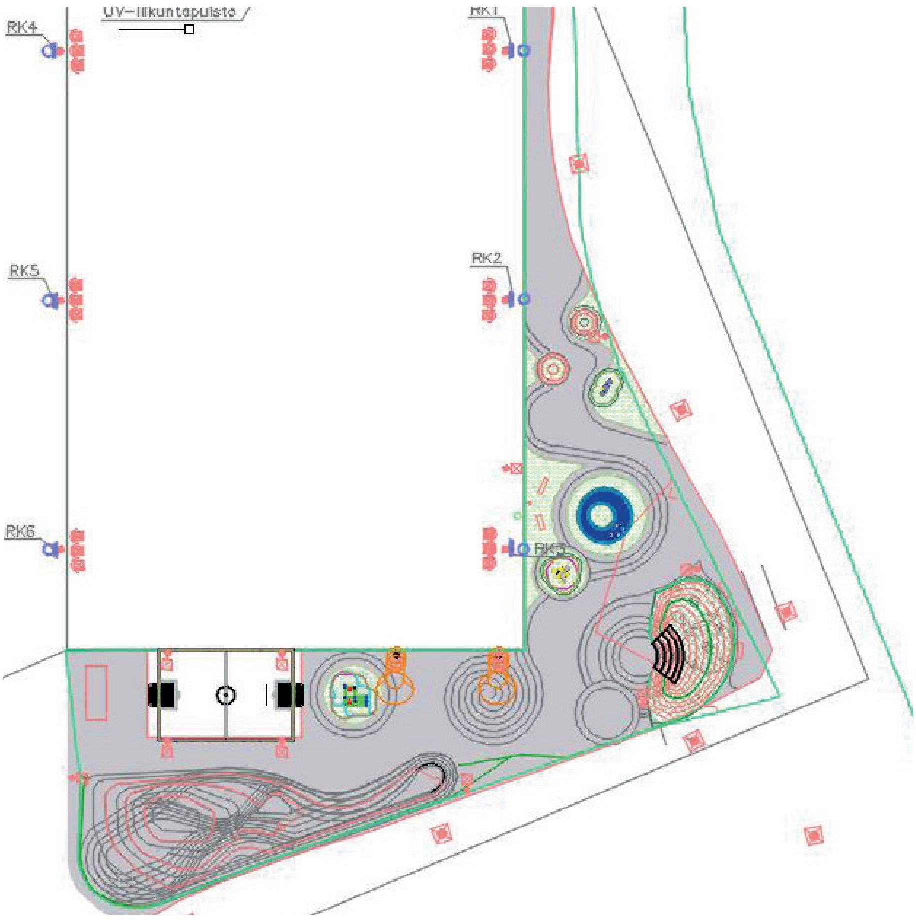


Civil 3D:

This is how the 3D model appears in Civil 3D from top view. The top view is automatically in parallel projection, meaning that it can be directly used as a ground plan and printed as pdf. It is already in DWG format.

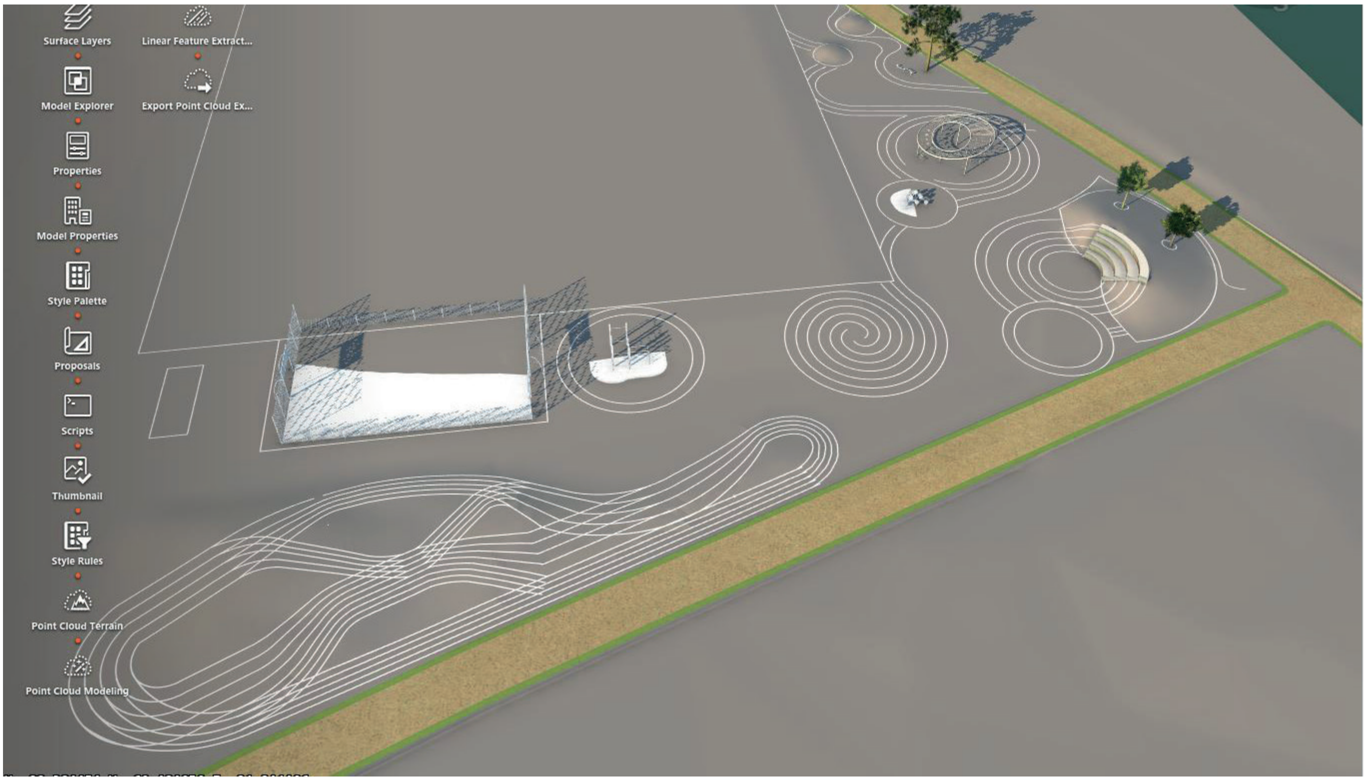


However, because rasters cannot be projected on surface, they must be shown as 2D objects. In this case, the original CAD drawing is referenced in Civil 3D.



Infraworks:

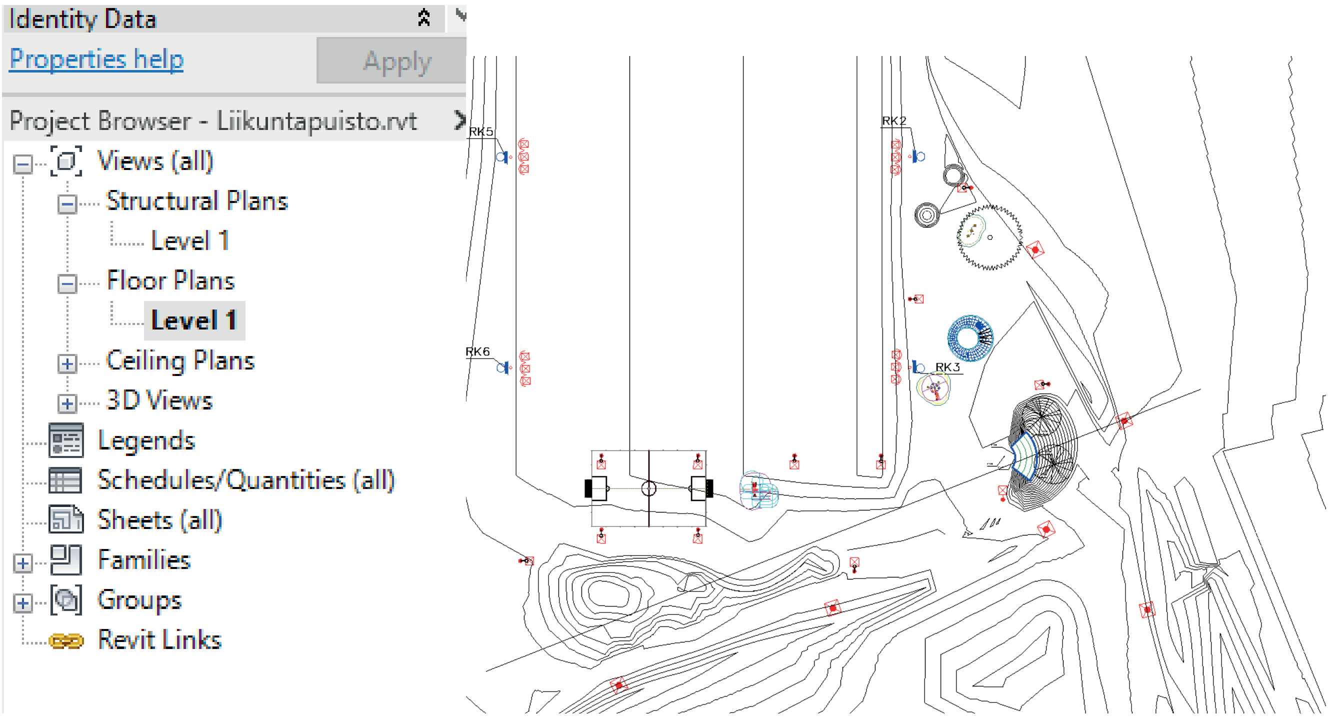
For viewing purposes, the lines on the surface were brought into Infraworks as a SHP file and set as "Watersheds".



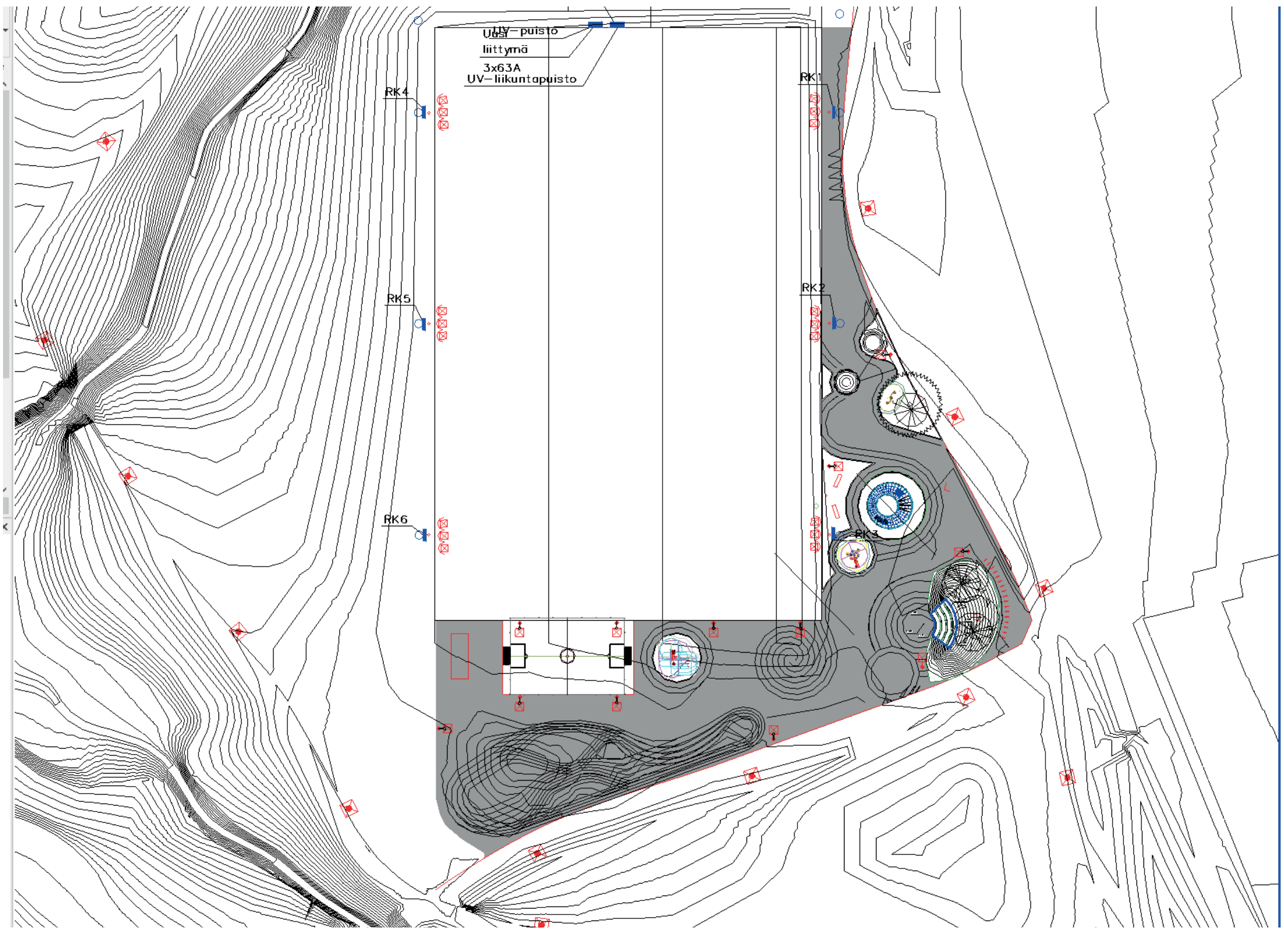
The model can be set to be in top view. However, Infraworks does not have the option to set parallel projection and the resulting plan cannot be printed as pdf or exported as DWG.

Revit:

Revit has a list of all drawings in the 3D model, including floor plans and sections. This makes the drawings easy to navigate.

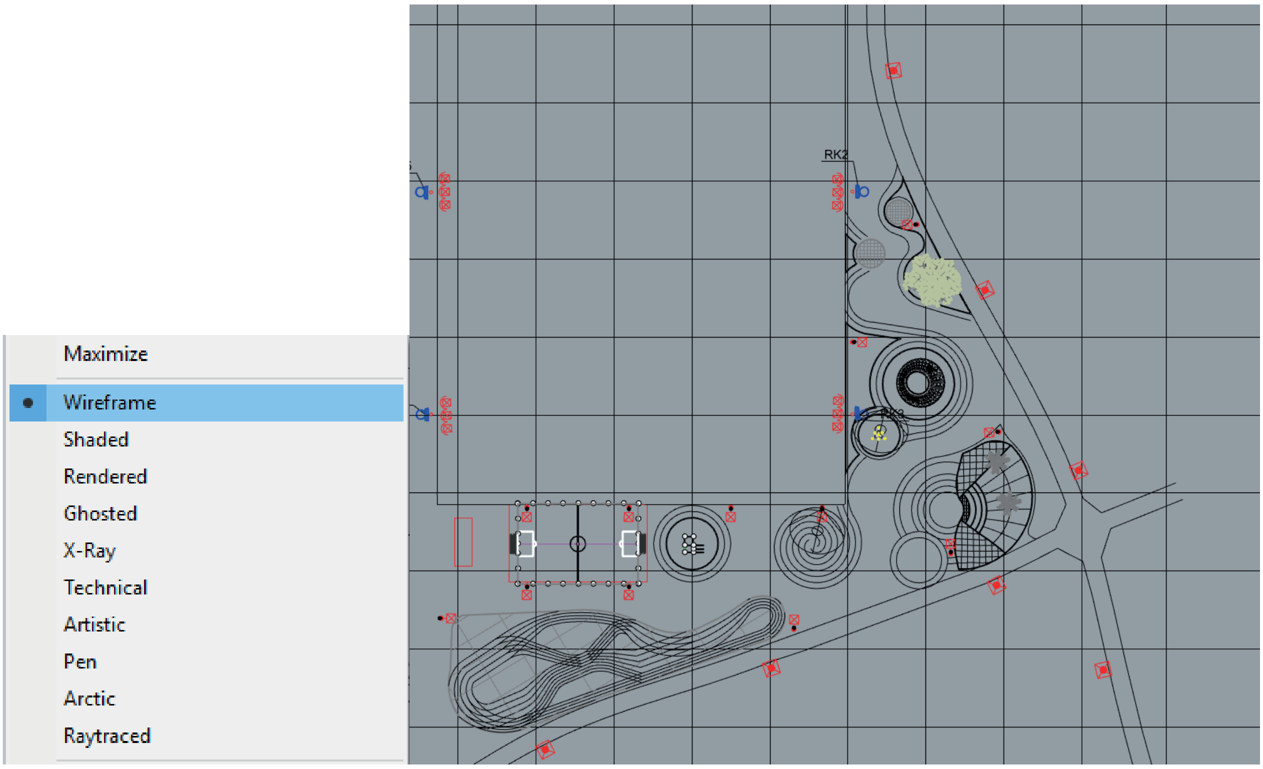


Lines cannot be projected on Revit toposurface (however areas can be outlined), so the lines are shown in the linked CAD ground plan in 2D instead.



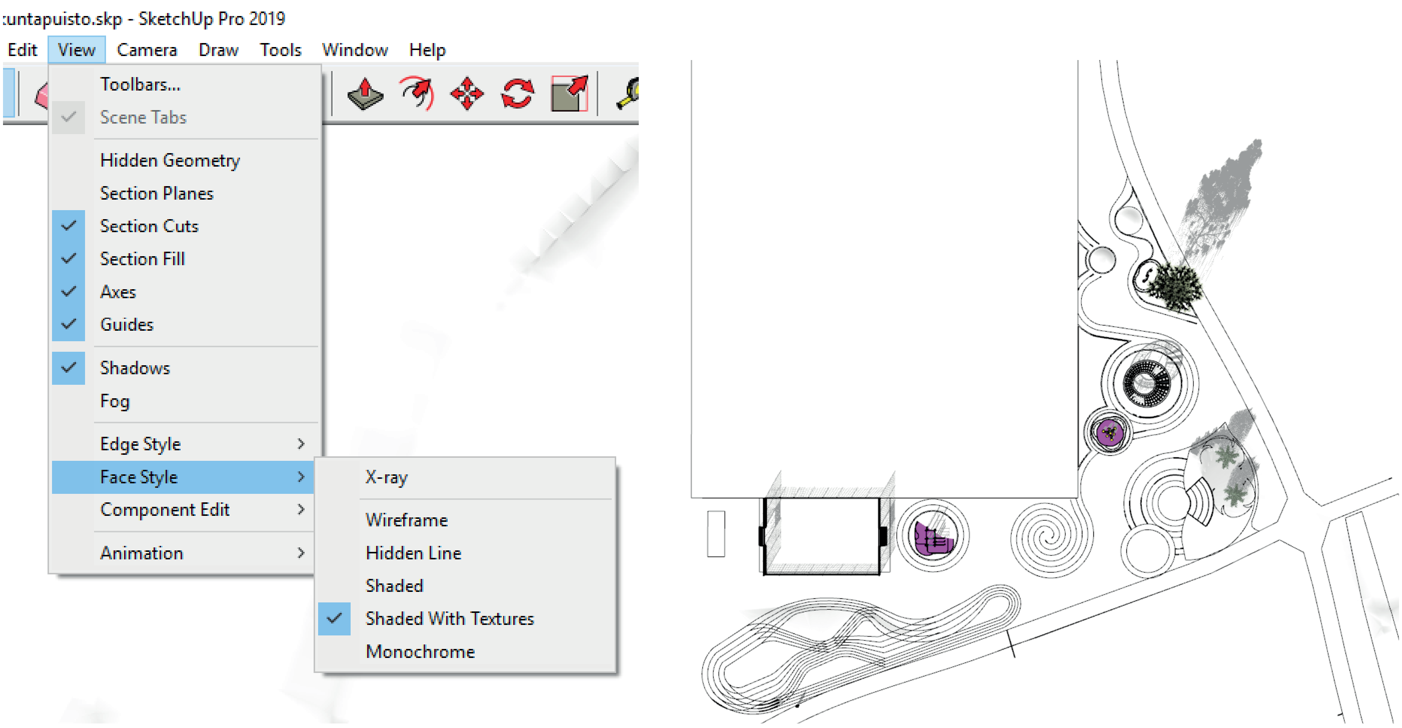
Rhino 3D:

Rhino has a default top view that shows the plan in parallel projection. In addition to wireframe mode, there is technical dtrawing mode that can make it easier to print a more finished-looking ground plan. The ground plan can be printed as pdf and exported as dwg.

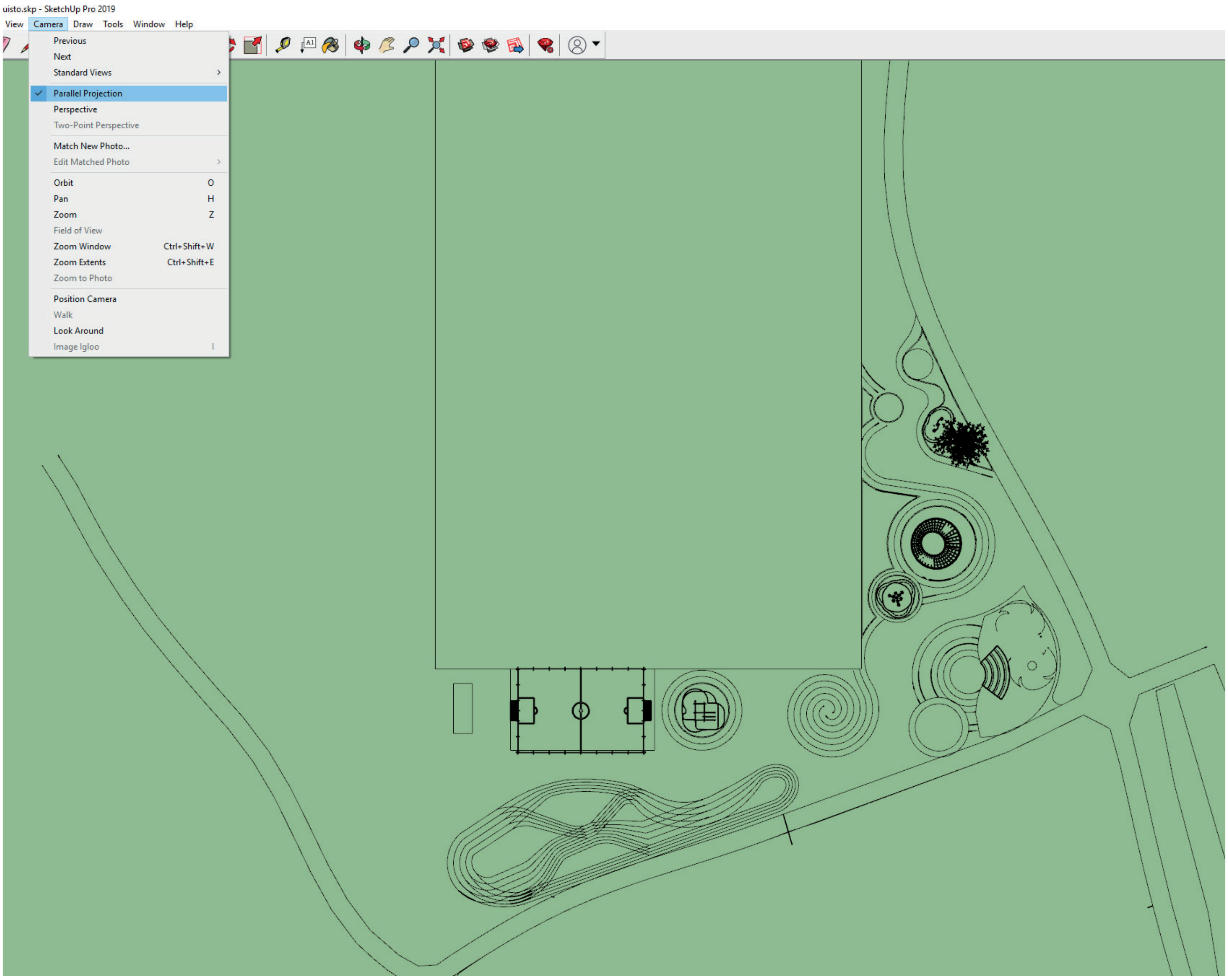


Sketchup:

Sketchup has parallel projection and top view available. The drawing can be printed as pdf and exported as dwg (in Sketchup Pro.)



However, there are some additional settings that other software do not require. The top view is not saved by default, so switching to perspective view requires changing these settings every time. This can be worked around by saving the top view as a scene.



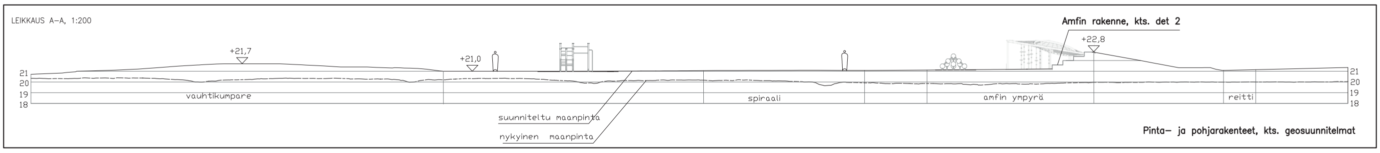
4.1. Verdicts

4. 2D drawings	**Civil 3D**	**Infraworks**	**Revit**	**Rhino 3D**	**Sketchup Pro**
4.1. Site plan	Top view is a standard view that is in parallel projection. Can print, is saved as dwg.	Cannot set parallel projection. Can take a screenshot.	Floor plan is a standard drawing document that is in parallel projection. Can print and convert to dwg.	Top view is a standard view that is in parallel projection. Can print and convert to dwg.	Must set top view and parallel projection separately. Can print and convert to dwg.

4.2. Section

For this project, two sections were created to show the use of space and how the created landforms differ from the current situation. The original sections were made using Civil 3D to create a frame for the section and Autocad Map 3D to draw in the details in 2D.

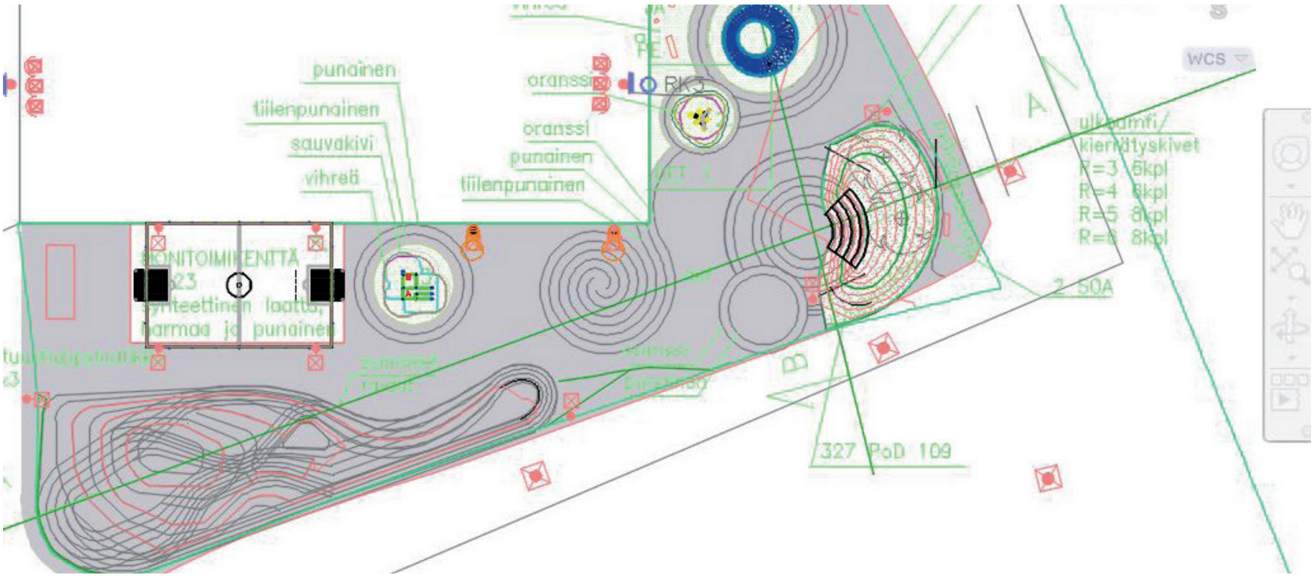
For this comparison, the section is drawn in the same location as the following section:



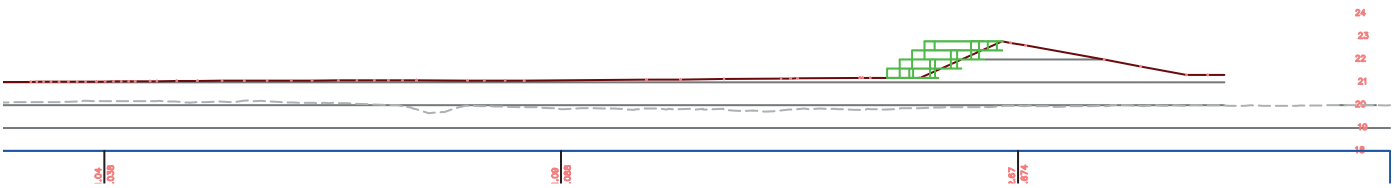
The comparison looks at how well the section-creating tools work in each software - how far can we get with the section without having to manually draw 2D shapes? Only the designed landforms are included in the comparison, because the existing terrain was not imported to the test models. However it can be assumed that the existing landform would be shown in the section the same as the designed landforms.

Civil 3D:

In Civil 3D, a line has to be transformed to an alignment, which can then be used to create a profile.



Below is the profile view placed into the drawing. Note that only objects located on the section alignment can be projected into the section. Here the steps of the amphitheater are shown along with the landforms. The background is not seen.

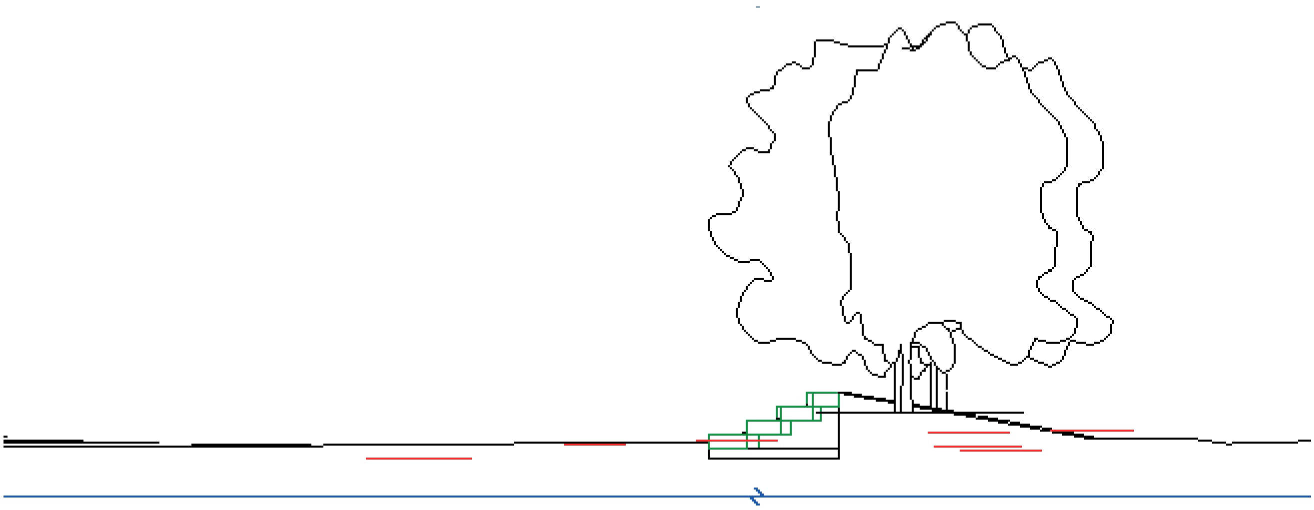


Infraworks:

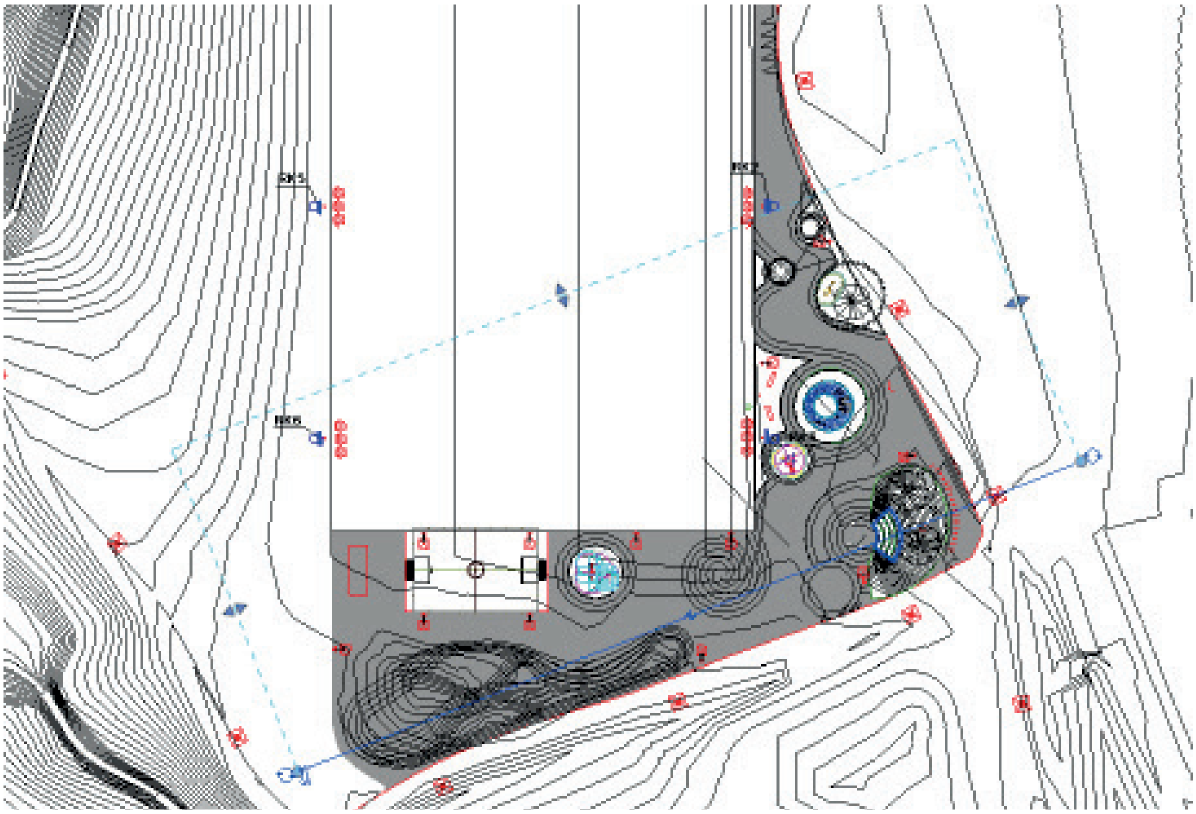
Infraworks does not have a tool for creating sections.

Revit:

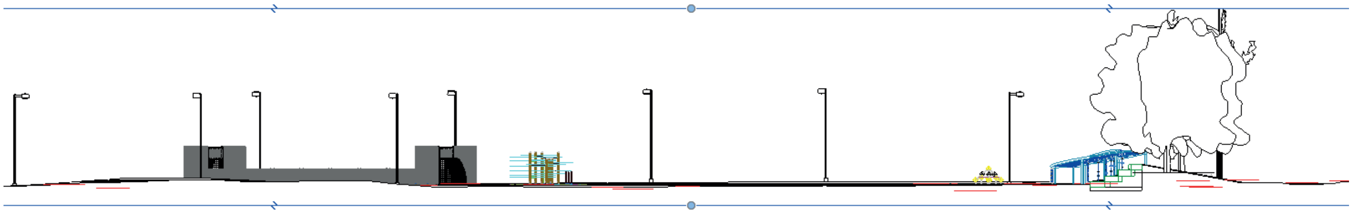
Revit has a section tool that adds the created section into the list of drawings in the 3D model. The section can be found on this list by name. The section is shown zoomed in below.



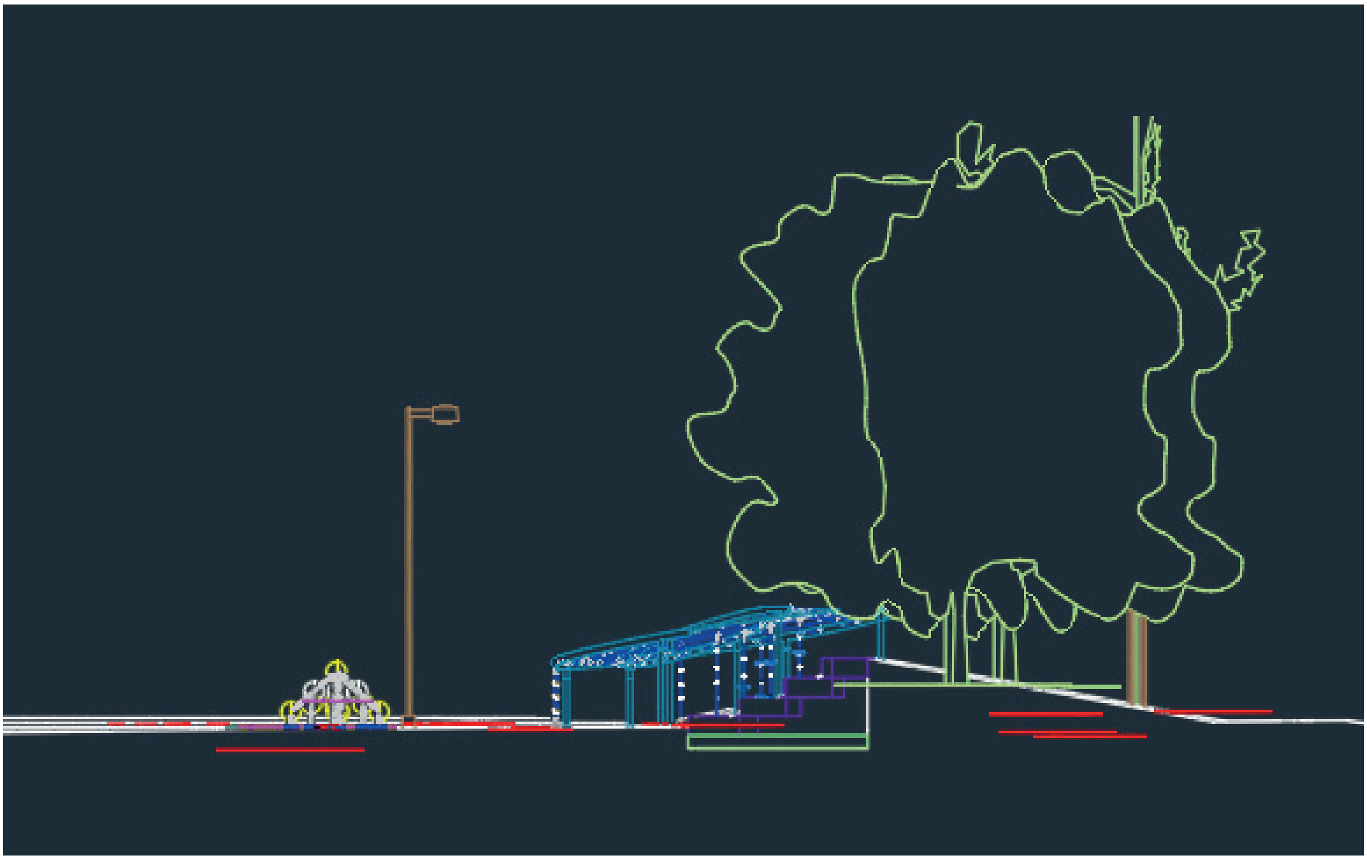
Everything in the 'section area' is shown in the section. The 'section area' is shown in blue below.



Making the section area larger allows to show more of the objects that are in the background and not directly on the section line.



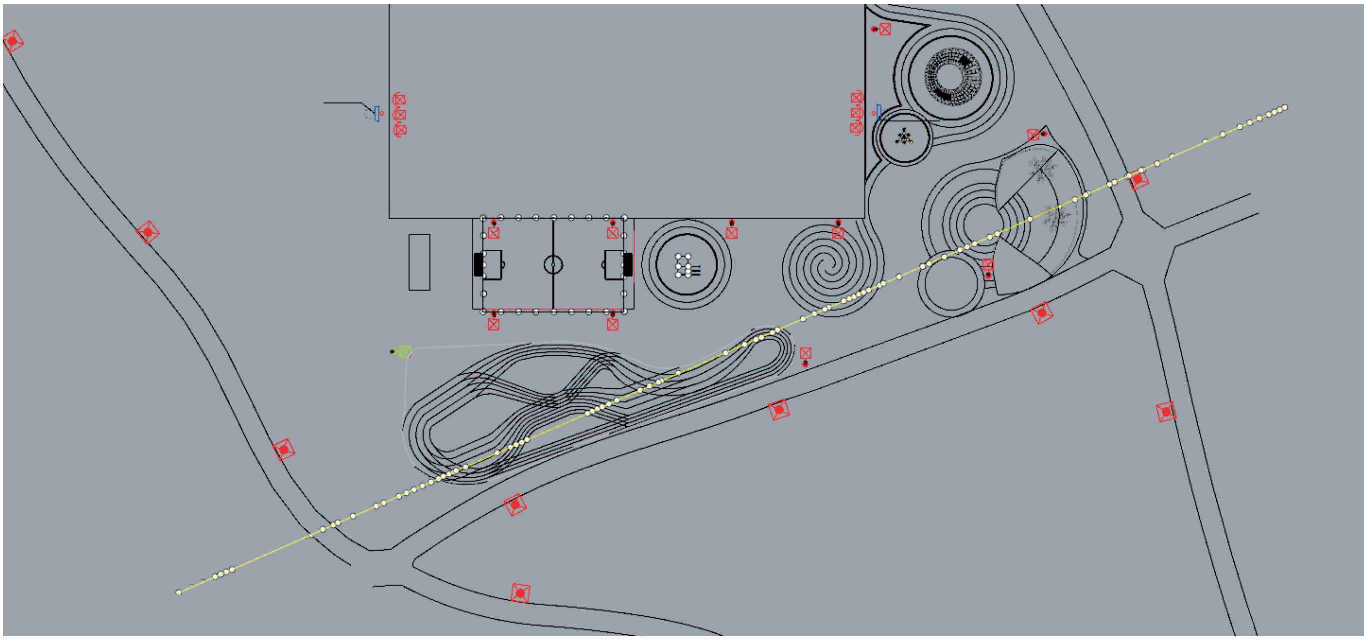
PDF of section. Here the section area has been enlarged to show more of the background objects.



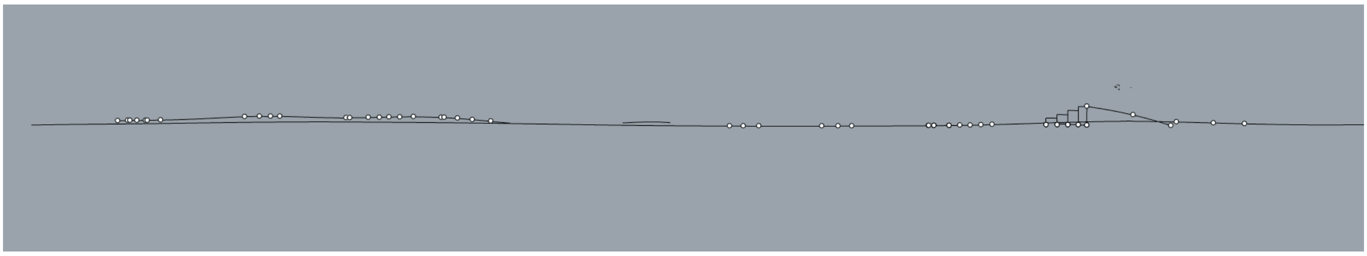
Close-up of DWG of section.

Rhino 3D

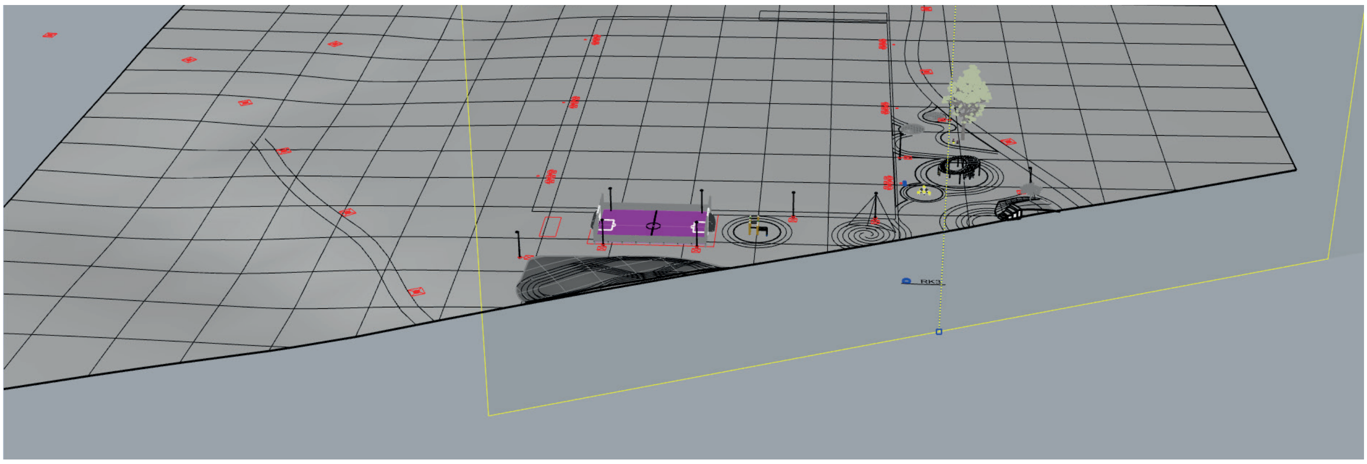
Rhino has a simple section command that involves drawing the section line.



After the section line is drawn, the section has to either be rotated or the view set to face the section. Rotating the section is a more simple process. Below the section is shown rotated. It can be exported as dwg.

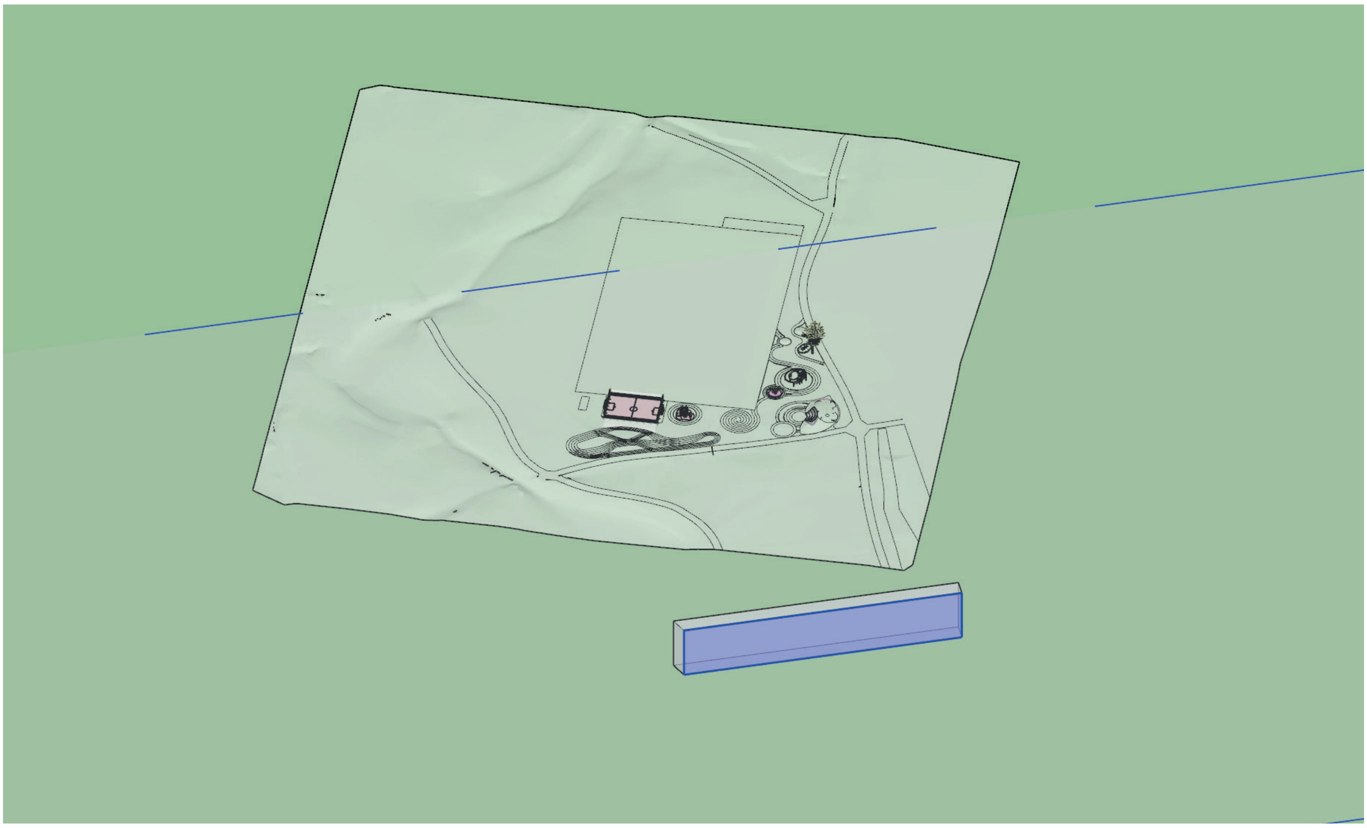


The basic section tool in Rhino does not show background objects. However, there is a workaround for this involving the Make-2D and Clipping Plane commands that requires several manual steps to bring the camera to face the section. Note that the orientation of the C-Plane must be changed. Due to the length of the process, it is omitted from this comparison. Below is shown the clipping plane in action, which is the starting point.

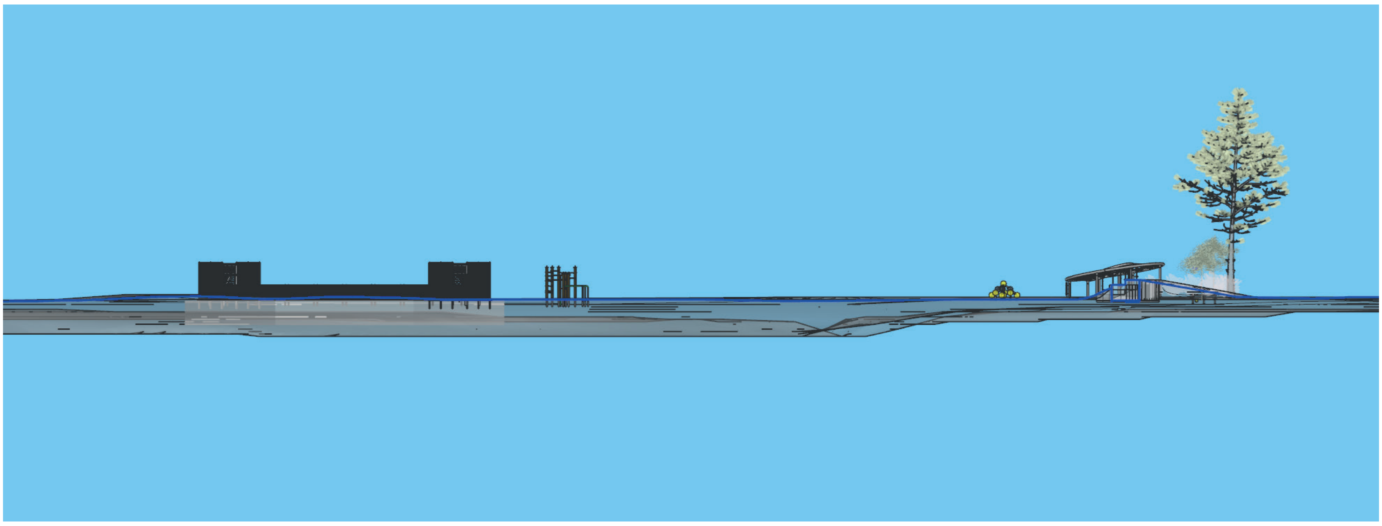


Sketchup:

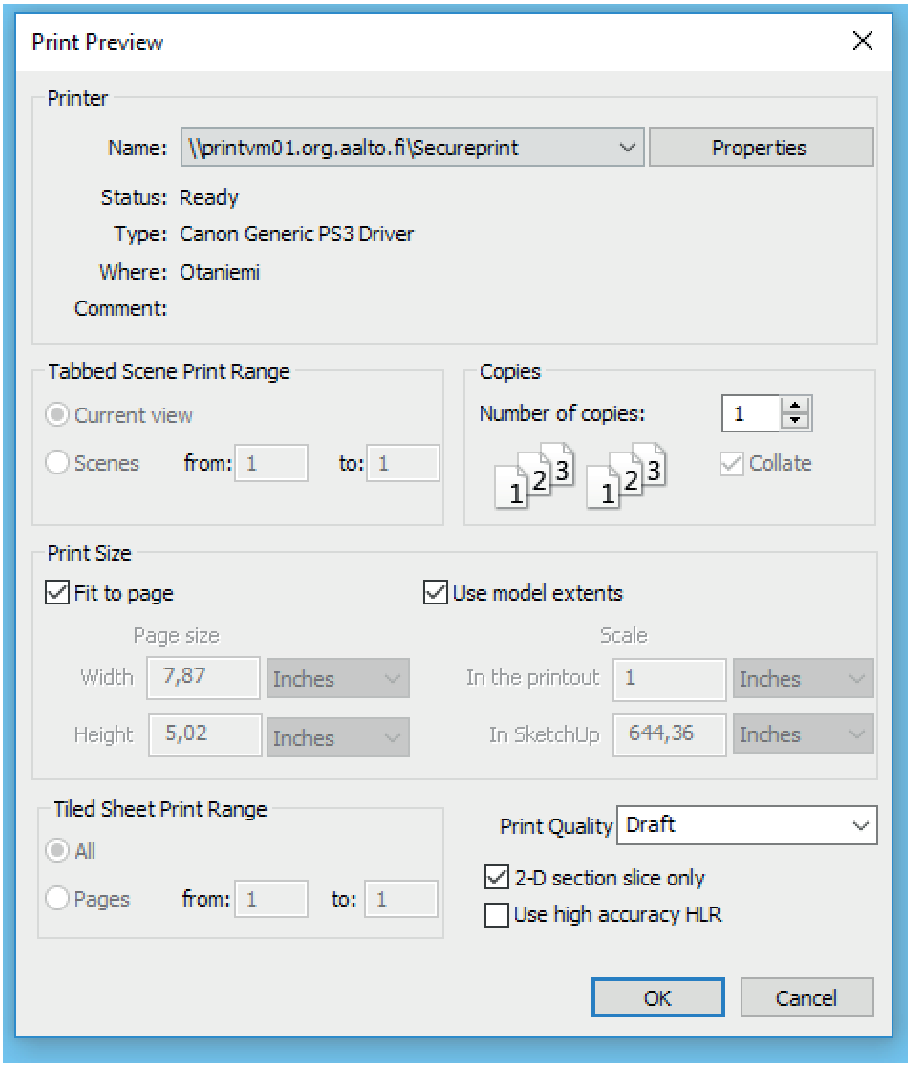
The section plane used in Sketchup is similar to the clipping plane in Rhino. To use the section plane, there must be a vertical surface in the direction of the section cut. This is used to place the clipping plane.



Then the clipping plane can be moved to the correct location, as shown above.



By right-clicking on the section plane and selecting “Align view”, the camera can be brought to face the section. In comparison to the complex workaround in Rhino, this method is far more efficient. Below is shown a close-up of the exported DWG.



By default everything in the background will be shown. While printing, however, it can be chosen to show the section line only by checking “2D section slice only”, shown below.

4.2. Verdicts

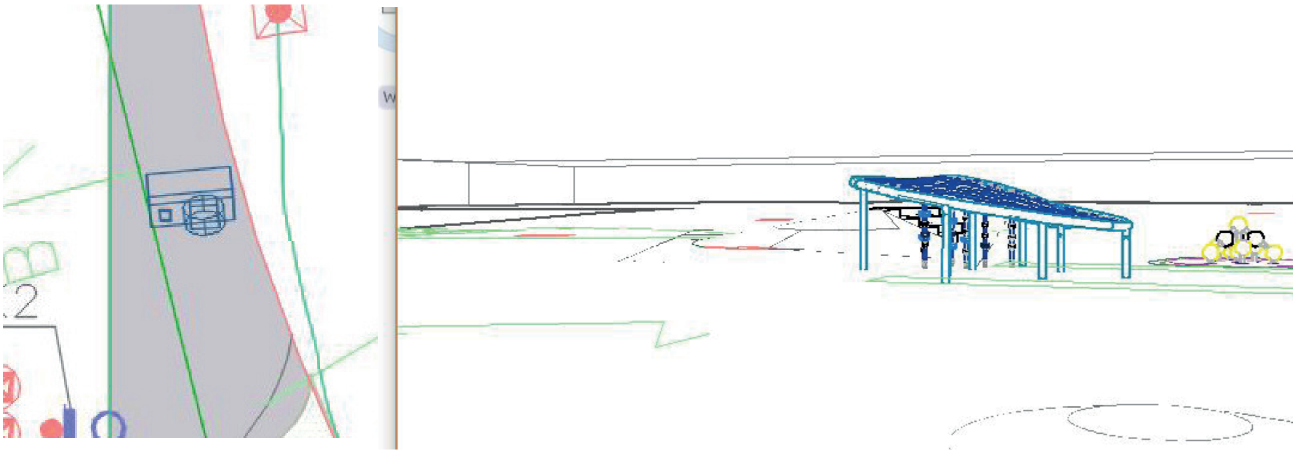
4. 2D drawings	Civil 3D	Infraworks	Revit	Rhino 3D	Sketchup Pro
4.2. Section	Has a dedicated tool. Is already in DWG format. Cannot show background objects in a section produced by the section tool.	Does not have a dedicated tool for creating a section.	Has a dedicated tool. Can be exported as DWG. Extents of the section view can be adjusted to show as much of the background objects as desired.	Has a dedicated tool. Can be exported as DWG. Showing background objects in the section requires a complex work-around.	Has a dedicated tool. Background objects are shown in the section view by default. The section line can be selected to be shown alone when printed.

5.1. Perspective view

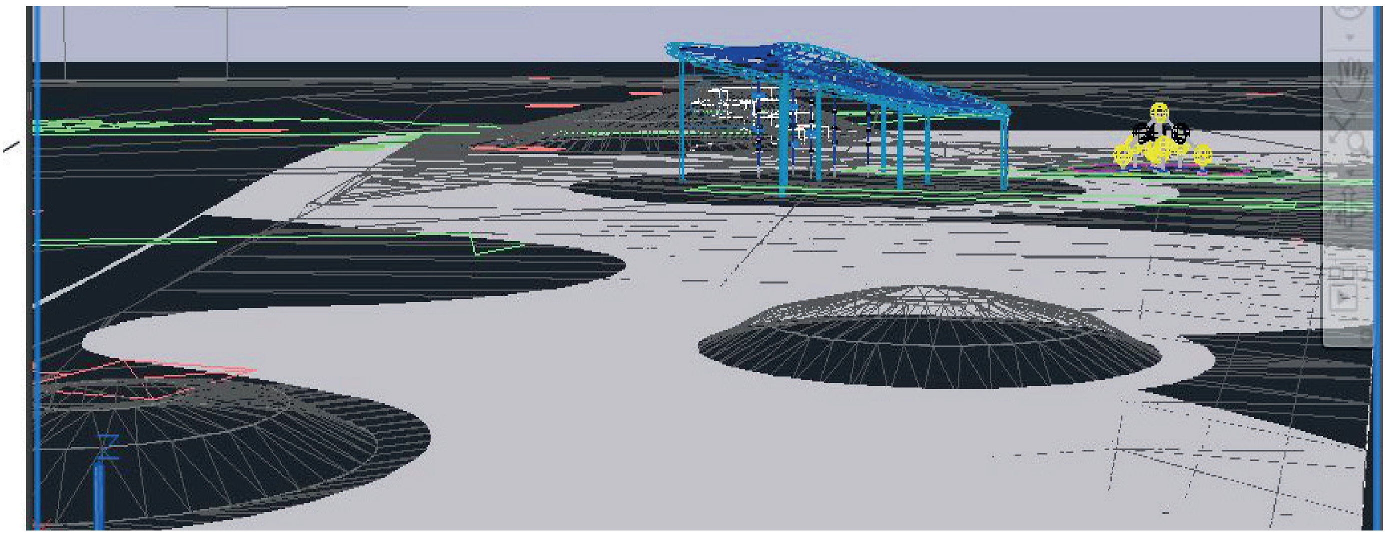
To get a realistic feel of the plan, it is important to get a ground level perspective view from a person's eye level. This is why the software should have a camera that can be placed on a certain height above the ground. Being able to then "walk" around the plan also gives a good idea of how the completed design would feel. The more realistic the representation can be, the better. According to He & Thompson (2011), the increase in detail helps eliminate ambiguity and increase the validity of visualization results. Note that this comparison only looks at viewing the model during modelling - not rendering. This is because rendering often requires an external plug-in that is not included in the software package. Note that setting materials is also not considered here, since rendering software also include their own materials. Rendering software will be able to produce much better results than shown here. However if the software includes a "rendered" view or can do real-time rendering, that will be included in this comparison. Real-time rendering is a desirable feature while virtually walking in the model.

Civil 3D:

In Civil 3D a camera can be placed in the model to create a perspective view from your chosen location. The height of the camera is set from the properties. The preview window shows how the perspective looks, as shown below.



After placing the camera you can set the view to show the camera that you have chosen, as shown below. Civil 3D has a few different display modes, such as wireframe, shaded and realistic. In this case the shaded and realistic view are not much better than wireframe, so wireframe is chosen, although it is the most primitive display method for a 3D model.



You can walk on the model with the command 3DWALK. However in this case the model is too slow to do so comfortably.

Infraworks:

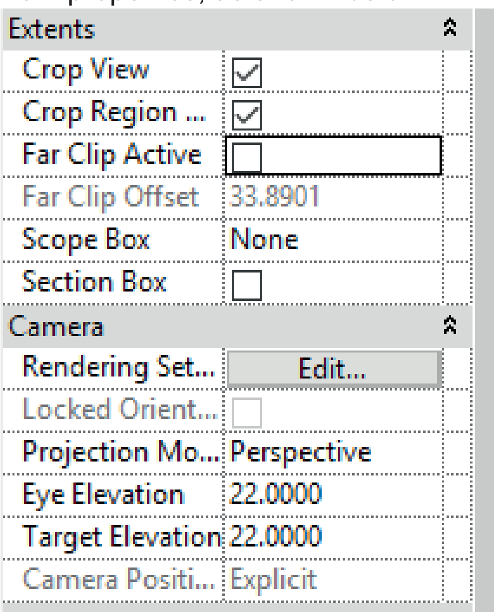
Infraworks does not have a separate camera tool for placing the camera, but navigating yourself to the correct spot is easy enough.

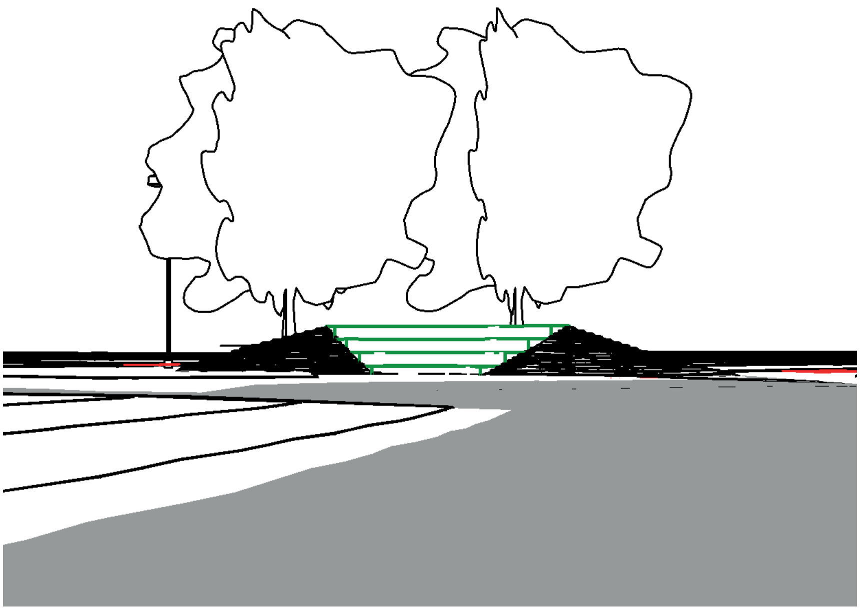
It is, however, possible to place camera paths to create a presentation video of moving around in the model. If you want to simulate walking on the ground, you can place an invisible road and use that as the path of the camera. [1]

The best thing about Infraworks is that it is always rendered in real-time, meaning that you do not have to do any separate renderings to get a realistic view of your model. In this comparison it has easily the best visual quality in perspective view.

Revit:

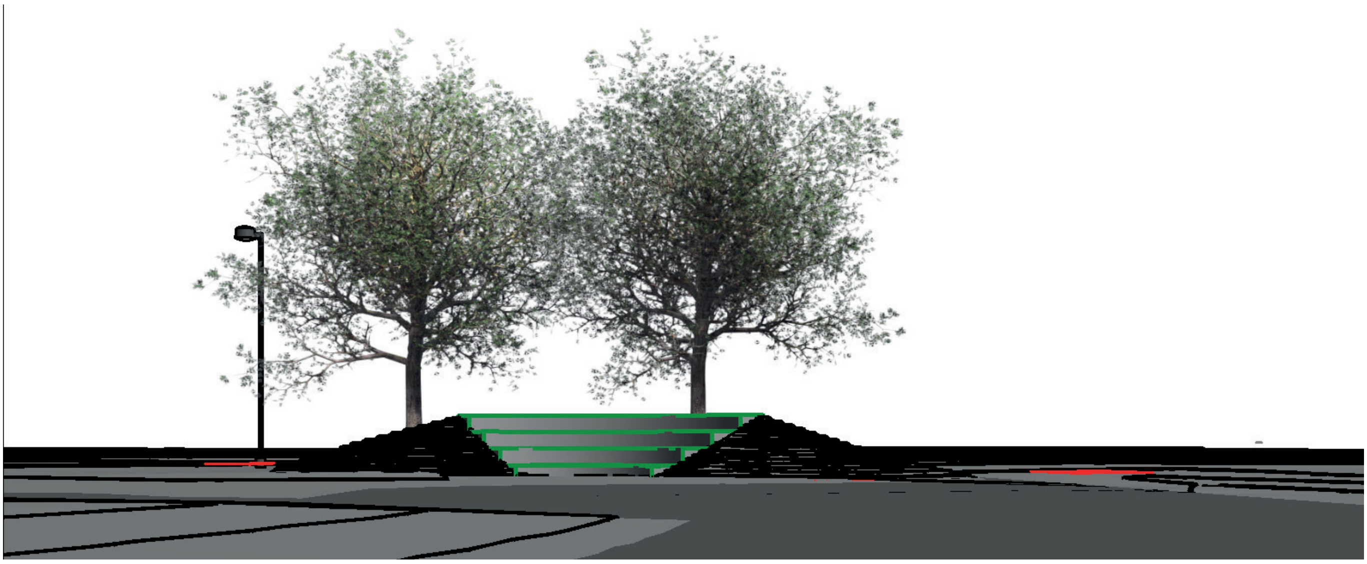
In Revit you can place a camera on the desired location. The Eye Elevation and Target Elevation are set from properties, as shown below.



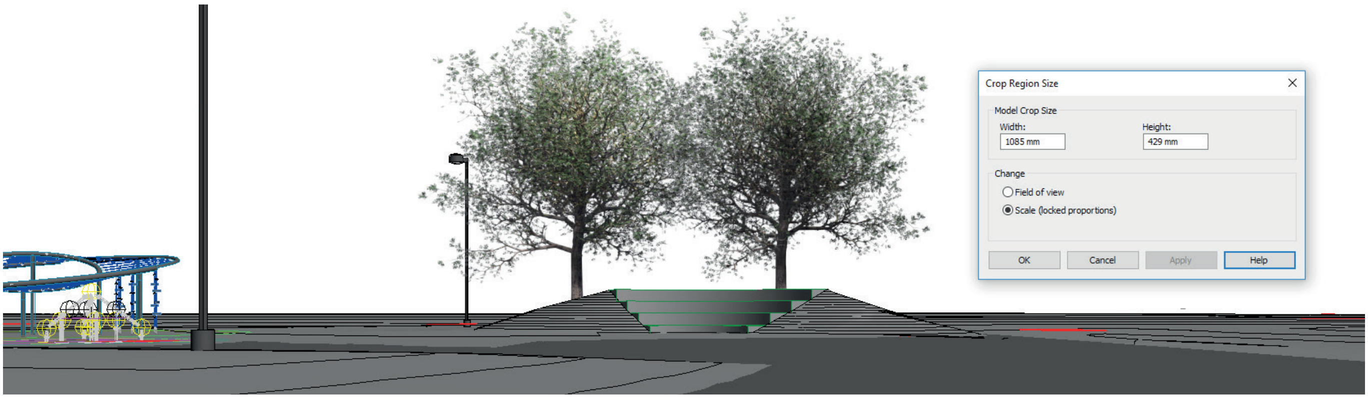


1 Knowledge.autodesk.com. (no date). To create a camera path from a component road. https://knowledge.autodesk.com/support/infraworks/learn-explore/caas/CloudHelp/cloudhelp/ENU/InfraWorks-UserHelp/files/GUID-9FD-FF1A0-E706-41A4-8CA2-F220A99FB5FD-htm.html Accessed 28.7.2019.

By changing the view mode to realistic, the model starts to look better. However, the lines are too thick.



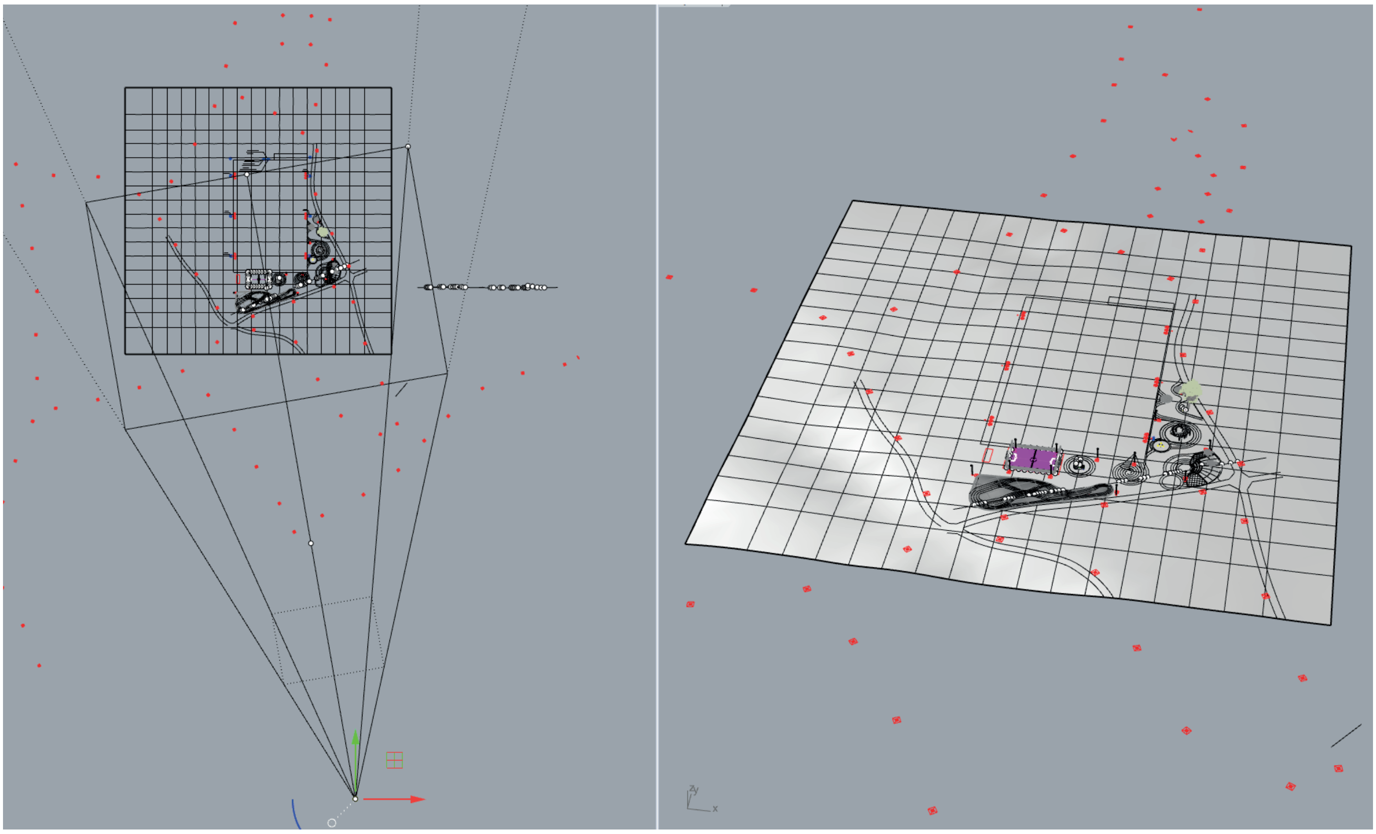
In the below image, the lines were set thinner by increasing the crop region size, thus increasing the resolution.

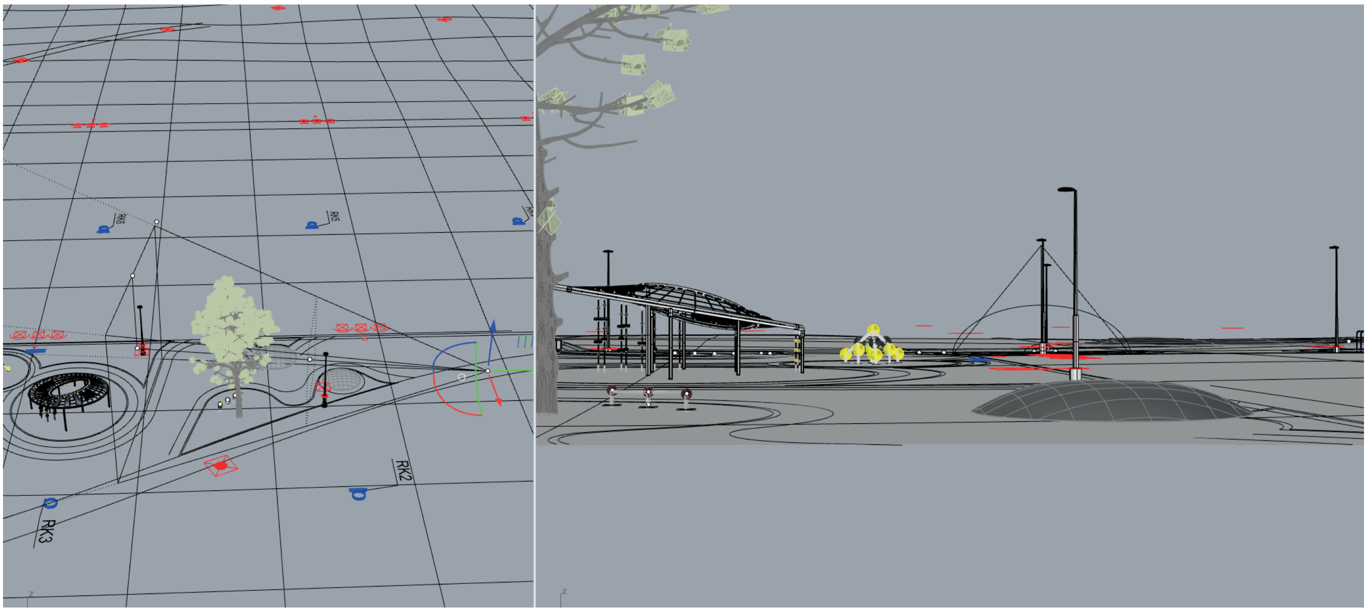


Below the model is shown from the same angle as the other examples, in “Realistic” view.

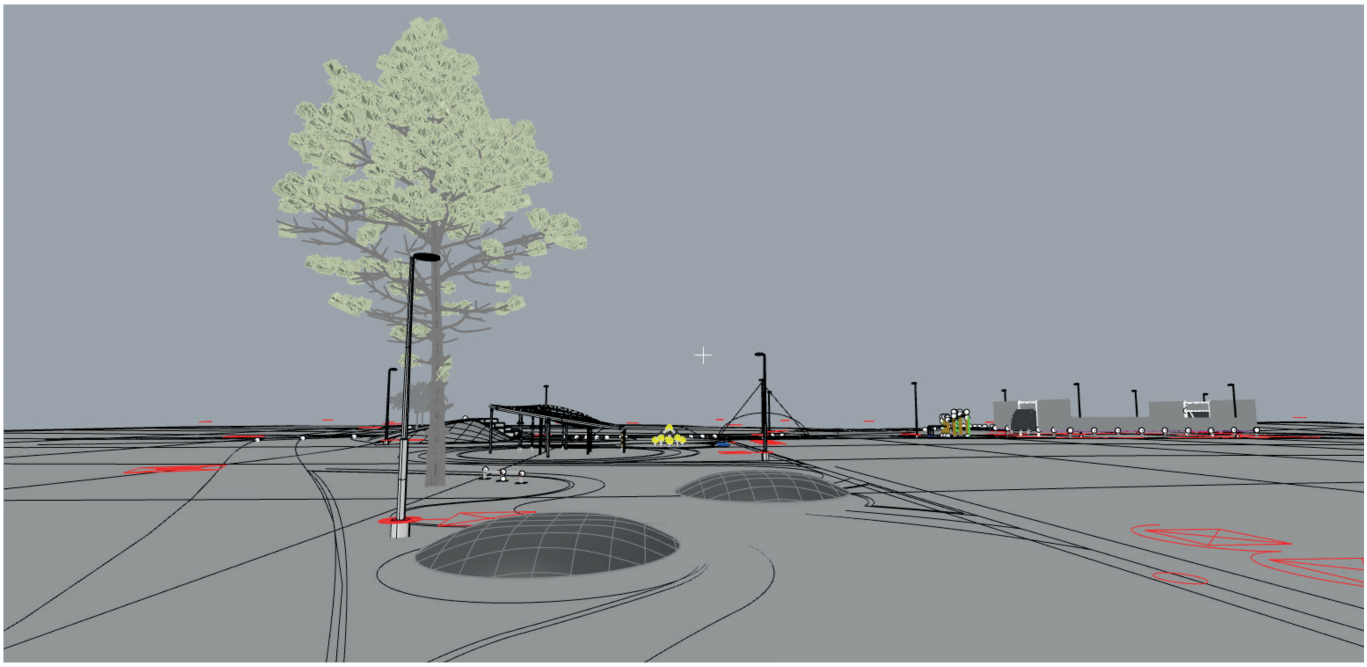
Rhino 3D:

In Rhino you can place a camera in the model, similar to Civil 3D and Revit. You need to find the correct eye level by snapping the camera to an object on the correct level.

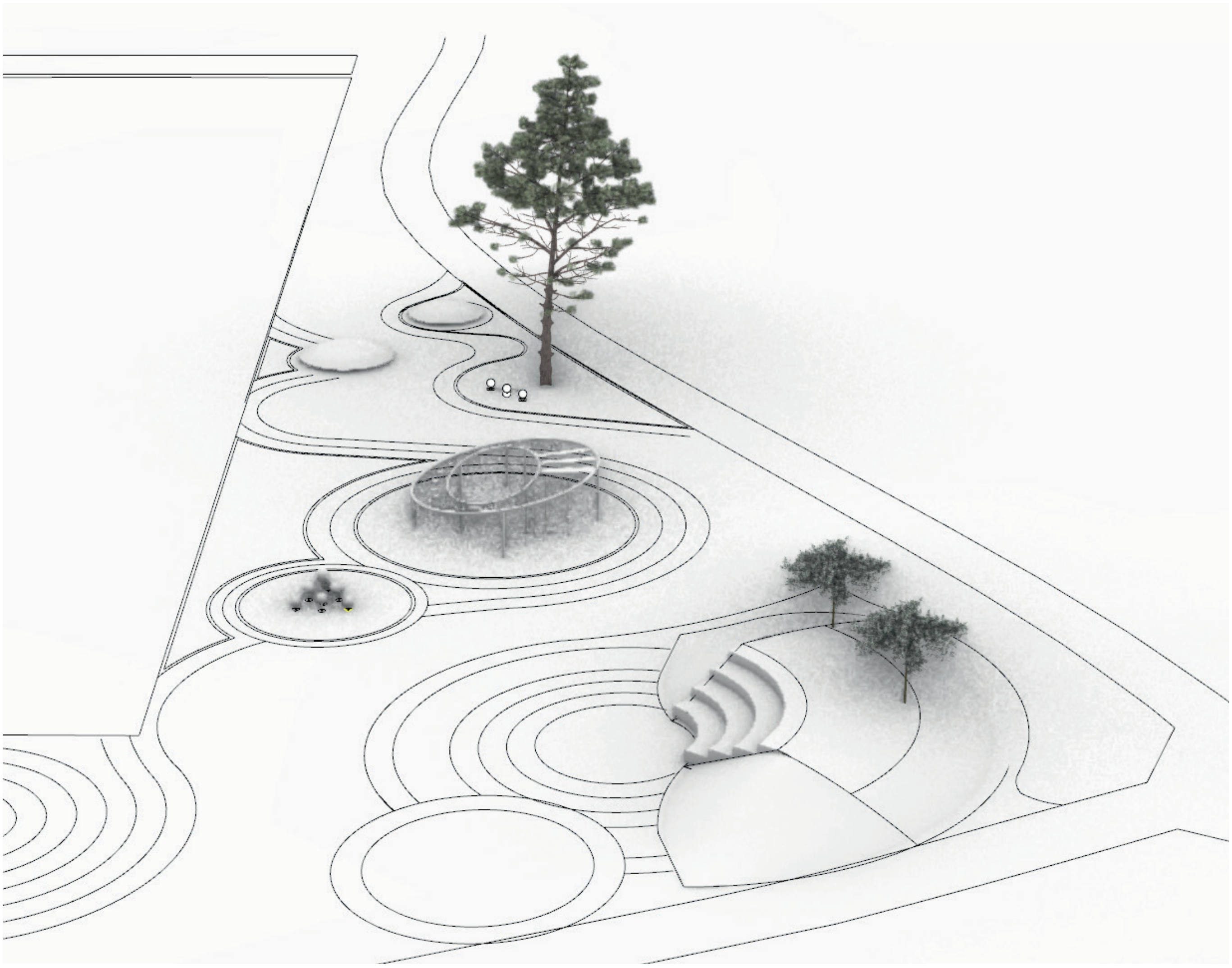




However, the perspective view shows unnecessary clipping of the ground, as seen above. The clipping can be reduced by setting the target of the camera closer.

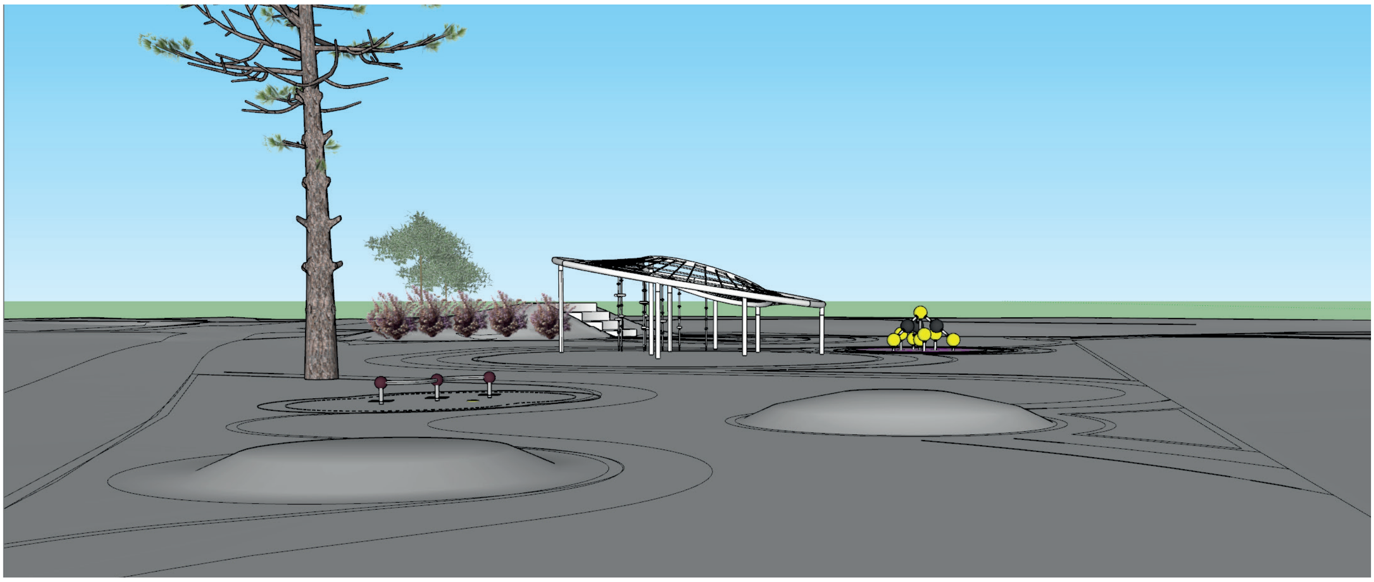


After placing the camera, it is possible to walk around using the WalkAbout command. This viewport is in shaded mode - however, "rendered" mode is also available. In this case it is too slow to use while using WalkAbout. The render is also of lower quality than a full rendering would be. Below is shown a view in rendered model view.



Sketchup:

In Sketchup you can place a camera on the surface, and then walk around the model. The benefit of Sketchup is that when you are placing the camera, it will automatically set on eye level above the ground. And as you are walking around, you will follow along the surface even on sloped terrain. This is a feature that the other software do not have.



5.1. Verdicts

5. Visualization level	Civil 3D	Infraworks	Revit	Rhino 3D	Sketchup Pro
5.1. Perspective view • moving in perspective view • quality of unrendered view	Can set camera on ground level. Can walk on ground level but in this case the model is too heavy. Does not stay on eye level while walking on sloped terrain. Worst visual quality in comparison.	Can set camera path on ground level. Does not stay on eye level while walking on sloped terrain. Best visual quality in comparison.	Can set camera on ground level. Can walk on ground level. Does not stay on eye level while walking on sloped terrain. Mediocre visual quality.	Can set camera on ground level. Can walk on ground level. Does not stay on eye level while walking on sloped terrain. Good visual quality.	Can set camera on ground level. Can walk on ground level. Stays on eye level while walking on sloped terrain. Mediocre visual quality.

6.1. File formats

As seen during the modeling process, being able to import different file types between software is important, as some objects such as urban furniture, vegetation or terrain models may only be available in a certain file format. Being able to export files is important for collaboration and if several software are used in the process.

One of the most common file formats used in landscape architecture in Finland is the DWG, which is the native format of AutoCAD. AutoCAD is the software most often used to make 2D drawings by landscape architects in Finland. Another format commonly used is the DGN, native to Microstation, which is similarly used to make 2D drawings.

Some universally used 3D model formats are FBX, OBJ and 3DS. The 3DS format is native to 3DS Max, but is commonly used to transfer between formats. These are used to export between software when the required native file type cannot otherwise be exported.

Raster formats are known for containing image data, but some of these formats can also contain terrain data, such as GeoTIFF and ASCII grid. These are important because the terrain data from Maanmittauslaitos comes in these formats, as explained in the chapter “1.3. Importing the existing terrain model“.

IFC is a BIM format that contains information about architectural 3D objects. According to the document “Integrating BIM technology to landscape architecture”, (Sipes, 2014), it is one of the most common standards associated with BIM, but it is driven by architects, so it is not capable of representing vegetation or landscape features. According to the report, virtually all BIM programs (though not all 3D modeling software) are able to import/export data using the IFC format.

LandXML is “an open, XML-based data standard for civil engineering, land planning, surveying, and transportation applications” according to the report “Integrating BIM technology to landscape architecture” (Sipes, 2014). The publication states that a LandXML data file stores surface point data and triangle faces used to create triangulated irregular networks (TINs), which are three-dimensional terrain models. It is mentioned that Autodesk Civil 3D provides the highest level of support for LandXML. In the MaisemaBIM report, 2019, it is stated that the Inframodel is a BIM file format that is based on the LandXML. The report states that few software can create an Inframodel file, but it can be manually made from a LandXML file by editing it as a text file, making this a time-consuming process. Thus the Inframodel file format is not considered in this evaluation.

Exporting	Civil 3D	Infraworks	Revit	Rhino 3D	Sketchup Pro
FBX	X	X	X	X	X
OBJ		X		X	X
3DS				X	X
DWG	Native file format		X	X	X
DGN	X			X	
IFC			X	X	X
LandXML	X				
RVT			Native file format		
3DM				Native file format	
SKP				X	Native file format
SQLite		Native file format			
GeoTIFF	X				
ASCII grid	?				

Figure 6. Exported file formats.

Importing	Civil 3D	Infraworks	Revit	Rhino 3D	Sketchup Pro
FBX	X	X		X	X
OBJ		X		X	
3DS	X	X		X	X
DWG	Native file format	?	X	X	X
DGN	X	X		X	
IFC		X	X		X
LandXML	X	X			
RVT		X	Native file format		
3DM	X			Native file format	
SKP		X		X	Native file format
SQLite		Native file format			
GeoTIFF		X			
ASCII grid	X	X			

Figure 7. Imported file formats.

From the compared software, Rhino 3D has the widest export options, and Infraworks has the widest import options. This is because Rhino 3D is at its core a rather traditional 3D modeling software for design, similar to 3DS Max. These kinds of software can be called core 3D modeling software because they are often used together with other software. This is why they need to have high compatibilty.

Infraworks, on the other hand, is at its core a visualization software. It is meant for bringing all the various models together and bringing them to life - this is why it has the widest available import options. Being able to bring your 3D model into Infraworks is crucial because you are unable to do most kinds of 3D modeling in Infraworks itself. It is supposed to be just the end product - a visualization. This is why it also has the fewest export options.

6.1. Verdicts

6. Compatibility	Civil 3D	Infraworks	Revit	Rhino 3D	Sketchup Pro
6.1.File formats	Few export options. Good amount of import options.	Few export options. The most import options.	Few export options. Few import options.	The most export options. Good amount of import options.	Good amount of export options. Good amount of import options.

5.2.3. Results chart

If the sub-task has comments in several colors, the scoring of the sub-task represents a weighted average value rather than an added value.

1. Setting up the 3D model	**Civil 3D**	**Infraworks**	
1.1. Geographic coordinate system libraries, geolocation	Coordinate system library. (5 pts)	Coordinate system library. (5 pts) Cannot model without defining a coordinate system.	
1.2. Importing the site plan	Yes, along with the coordinate system. (5 pts)	In theory yes, but in practise almost always results in errors. Can be imported in SHP format instead. (3 pts)	
1.3. Importing the existing terrain model from Maanmittauslaitos (ASCII grid, GeoTIFF and LAZ file formats)	Can open ASCII grid, GeoTIFF. (5pts)	Can open ASCII grid, GeoTIFF. (5 pts)	
1. Score (max 15 pts)	**15 pts**	**13 pts**	
2. Landforms	**Civil 3D**	**Infraworks**	
2.1. 3D modeling from contours	Yes, using meshes. (5 pts)	No. But some primitive terrain modeling is possible with the Coverage tool. (1 pts)	
2.2. Connecting to the existing terrain	Can connect surfaces that do not meet at egdes. Projecting edges of surface onto existing terrain before merging is not necessary, but recommended for a smoother transition. (5 pts)	No. (0 pts) Note that using the Coverage tool automatically shapes the current terrain.	
2.3. Resulting contours from surface • format and height values • accuracy	Yes. Is already in dwg format. Exported contours have height values. (5 pts) Accuracy: Contours are jagged when created from a mesh. No unintenional lines or deviations from landform. (4 pts)	No. (0 pts)	
2.4. Calculating volume	Has a dedicated tool. (5 pts)	Can measure volume of Coverage areas made in Infraworks. (2 pts)	
2. Score (max 25 pts)	**24 pts**	**3 pts**	
3. Other landscape elements	**Civil 3D**	**Infraworks**	
3.1. Water	Watershed and waterdrop analysis. (5 pts)	Watershed analysis. Visualization of still water and animated flow of water. (4 pts)	

Good (5-4 pts)
Intermediate / Inefficient (3-2 pts)
Barely functional / Non-functional (1-0 pts)
Notes

	Revit	Rhino 3D	Sketchup Pro
	Survey coordinate system that allows marking a coordinate point. (3 pts)	Geolocation for rendering shadows, no coordinate system library. (1 pts)	Google Earth geolocation that allows using the Google Earth model. (2 pts)
	Yes, but the project extents are too large with the Finnish coordinate system used. However, can be used after moving to origin. (3 pts)	Yes, but the project extents are too large with the Finnish coordinate system used. However, can be used after moving to origin. (3 pts)	No, crashes while opening the Skanssi.dwg that is set in the Finnish coordinate system. However, smaller fragments can be imported. (1 pts)
	Can open LAZ after being converted into RCP in Autodesk ReCap. (2 pts)	Can open ASC, but not ASCII grid, GeoTIFF or LAZ. However, can open ASCII grid with Grasshopper plugin. (3 pts)	Cannot open ASCII grid, GeoTIFF or LAZ. However, Google Earth terrain model can be used. (1 pts)
	8 pts	**7 pts**	**4 pts**
	Revit	**Rhino 3D**	**Sketchup Pro**
	Yes, using meshes. (5 pts)	Yes, using meshes or preferrably NURBS. (5 pts)	Yes, using meshes. (5 pts) Note that Sketchup Pro must be used to import DWGs.
	Can connect surfaces that do not meet at edges. It is best to modify the contours rather than the 3D model for a smoother transition. In cases when contours cannot be modified sufficiently, the terrain has to be modified vertex-by-vertex, which is inefficient. (4 pts)	No way to merge NURBS surface with mesh. Mesh to NURBS conversion is not always succesful. Two NURBS surfaces can be joined, but two NURBS patches will pose difficulties due to the edges not meeting. (2 pts)	Connecting two TIN surfaces into one would require an unnecessary amount of manual work with large surfaces. (1 pt)
	Yes. Can be saved in dwg format in ground plan view. However, the exported contours do not have heights. (3 pts) Accuracy: Contours are jagged when created from a mesh. No unintenional lines or deviations from landform. (4 pts)	Yes. Can be saved in dwg format. Exported contours have height values. (5 pts) Accuracy: Contours are very smooth when created from NURBS. Contours can include unintentional mounds or hills. (3 pts)	Yes. Can be saved in dwg format in ground plan view. However, the exported contours do not have heights. (3 pts) Accuracy: Contours are jagged when created from a mesh. Includes some unwanted triangulation lines. (3 pts)
	Has a dedicated tool. (5 pts)	Has a dedicated tool. (5 pts)	Theoretically possible, but would require a lot of manual work with large surfaces. (2 pts)
	21 pts	**20 pts**	**14 pts**
	Revit	**Rhino 3D**	**Sketchup Pro**
	Visualization of still water. (1 pts)	Visualization of still water. Some analysis may be possible with scripting or plug-ins. (3 pts)	Visualization of still water. (1 pts)

3.2. Routes	Can project as lines. Can create as separate surface for coloring. Extensive tools for determining road slopes, sections, etc. (5 pts)	Can project as lines. Parametric tools for roads (including sections). (5 pts)	
3.3. Structures (amphitheater + terrain modification)	Seating stairs as extrusion. Landform from breaklines and feature lines. (5 pts)	Seating stairs as buildings. Landform must be exported. (3 pts)	
3.4. Playground equipment / street furniture	Opens CAD 3D models well. Object materials retained. Object height can be input in properties as height from sea level. (5 pts)	Cannot use CAD format - another software must be used to convert the file. Materials not retained in this case. Object automatically placed on terrain. (3 pts)	
3.5. Vegetation	Only slight problems with importing trees. Detailed 3D models of trees are too heavy, causing the software to freeze. No tree library. (3 pts)	Problems with importing trees. Includes own tree library. Runs smoothly. (4 pts)	
3.5. Lighting	Sunlight. Streetlights can be created with a 3D model and a spotlght. Moving streetlights is unacceptably slow due to the amount of detail in the model. (3 pts)	Sunlight. No spotlights. (1 pts)	
3. Score (max 30 pts)	**26 pts**	**20 pts**	
4. 2D drawings	**Civil 3D**	**Infraworks**	
4.1. Site plan	Top view is a standard view that is in parallel projection. Can print, is saved as dwg. (4 pts)	Cannot set parallel projection. Can take a screenshot. (1 pts)	
4.2. Section	Has a dedicated tool. Cannot show background objects in a section produced by the section tool. (2 pts)	Does not have a dedicated tool for creating a section. (0 pts)	
4. Score (max 10 pts)	**6 pts**	**1 pts**	
5. Viewing the 3D model	**Civil 3D**	**Infraworks**	
5.1. Perspective view • moving in perspective view • quality of unrendered view	Can set camera on ground level. Can walk on ground level but in this case the model is too heavy. Does not stay on eye level while walking on sloped terrain. (2 pts) Worst visual quality in comparison. (2 pts)	Can set camera path on ground level. Does not stay on eye level while walking on sloped terrain. (3 pts) Best visual quality in comparison. (5 pts)	
5. Score (max 10 pts)	**4 pts**	**8 pts**	
6. Compatibility	**Civil 3D**	**Infraworks**	
6.1. File formats	Few export options. (2 pts) Good amount of import options. (4 pts)	Few export options. (2 pts) The most import options. (5 pts)	
6. Score (max 10 pts)	**6 pts**	**7 pts**	
Across all categories	**Civil 3D**	**Infraworks**	
Score (max 100 pts)	**81 pts**	**52 pts**	

Cannot project as lines, but can make sub-surface or split for coloring. However, the selection method is slow. (3 pts)	Can project as lines. Can split into separate surface for coloring. (4 pts)	Can project as lines. Cannot split into separate surface, but can color with a material. (4 pts)
Seating stairs as floors. Landform from contours. (4 pts)	Seating stairs as extrusion. Landform from construction lines. Gives the smoothest result. (5 pts)	Seating stairs as extrusion. Landform from contours. (4 pts)
Some problems with importing CAD files. Some materials retained. Object height can be input in properties as height from sea level. If families are used, the object is placed on terrain automatically. (4 pts)	Opens CAD 3D models well. Materials retained if layer color matches layer material. Object must be dragged to correct level using guidelines. (3 pts)	Opens CAD models slowly. Most materials retained. Object must be dragged to correct level using guidelines. (3 pts)
Problems with importing trees. Detailed 3D models of trees are too heavy. Includes own tree library that runs smoothly. (4 pts)	No problems with importing trees. The software runs smoothly with a small amount of detailed tree models. No tree library. (4 pts)	No problems with importing trees. Detailed 3D trees can be substituted with 2D face-me objects from Sketchup Warehouse to make the software run smoothly. (4 pts)
Sunlight. Revit light family contains a street light that includes a spotlight. (5 pts)	Sunlight. Streetlights can be created with a 3D model and a spotlght. However, spotlights cannot be placed inside a block, which would make duplicating the street light easier. (4 pts)	Sunlight. No spotlights. (1 pts)
21 pts	**24 pts**	**17 pts**
Revit	**Rhino 3D**	**Sketchup Pro**
Floor plan is a standard drawing document that is in parallel projection. Can print and convert to dwg. (4 pts)	Top view is a standard view that is in parallel projection. Can print and convert to dwg. (4 pts)	Must set top view and parallel projection separately. Can print and convert to dwg. (3 pts)
Has a dedicated tool. Extents of the section view can be adjusted to show as much of the background objects as desired. (4 pts)	Has a dedicated tool. Showing background objects in the section requires a complex workaround. (3 pts)	Has a dedicated tool. Background objects are shown in the section view by default. The section line can be selected to be shown alone when printed. (4 pts)
8 pts	**7 pts**	**7 pts**
Revit	**Rhino 3D**	**Sketchup Pro**
Can set camera on ground level. Can walk on ground level. Does not stay on eye level while walking on sloped terrain. (3 pts) Mediocre visual quality. (3 pts)	Can set camera on ground level. Can walk on ground level. Does not stay on eye level while walking on sloped terrain. (3 pts) Good visual quality. (4 pts)	Can set camera on ground level. Can walk on ground level. Stays on eye level while walking on sloped terrain. (5 pts) Mediocre visual quality. (3 pts)
8 pts	**7 pts**	**8 pts**
Revit	**Rhino 3D**	**Sketchup Pro**
Few export options. (2 pts) Few import options. (2 pts)	The most export options. (5 pts) Good amount of import options. (4 pts)	Good amount of export options. (4 pts) Good amount of import options. (4 pts)
4 pts	**9 pts**	**8 pts**
Revit	**Rhino 3D**	**Sketchup Pro**
70 pts	**74 pts**	**58 pts**

1. Setting up the 3D model	Civil 3D	Infraworks	Revit	Rhino 3D	Sketchup
2. Landforms	Civil 3D	Infraworks	Revit	Rhino 3D	Sketchup
3. Other landscape elements	Civil 3D	Infraworks	Revit	Rhino 3D	Sketchup
4. 2D drawings	Civil 3D	Infraworks	Revit	Rhino 3D	Sketchup
5. Viewing the 3D model	Civil 3D	Infraworks	Revit	Rhino 3D	Sketchup
6. Compatibility	Civil 3D	Infraworks	Revit	Rhino 3D	Sketchup

Overall	Civil 3D	Infraworks	Revit	Rhino 3D	Sketchup

Rankings

Setting up the 3D model
1. Civil 3D 15 pts
2. Infraworks 13 pts
3. Revit 8 pts
4. Rhino 3D 7 pts
5. Sketchup Pro 3 pts

Landforms
1. Civil 3D 24 pts
2. Revit 21 pts
3. Rhino 3D 20 pts
4. Sketchup Pro 14 pts
5. Infraworks 3 pts

Other landscape elements
1. Civil 3D 26 pts
2. Rhino 3D 24 pts
3. Infraworks 20 pts
3. Revit 21 pts
5. Sketchup Pro 17 pts

2D drawings
1. Revit 8 pts
2. Sketchup Pro 7 pts
2. Rhino 3D 7 pts
2. Civil 3D 6 pts
3. Infraworks 1 pts

Viewing the 3D model
1. Infraworks 8 pts
1. Revit 8 pts
1. Sketchup Pro 8 pts
4. Rhino 3D 7 pts
5. Civil 3D 4 pts

Compatibility
1. Rhino 3D 9 pts
2. Sketchup Pro 8 pts
3. Infraworks 7 pts
4. Civil 3D 6 pts
5. Revit 4 pts

5.3. Reflections

5.3.1. Software comparison

Overall the differences between software performance were found to be relatively small - but within some specific tasks differences were high. It can be concluded that none of compared software is clearly above others - rather all software have their own strengths and weaknesses in specific areas of 3D modeling.

More specifically, Civil 3D, Revit and Rhino 3D were found to be almost equal when it comes to overall functionality - but Infraworks and Sketchup were found to have more niche uses in comparison.

Sketchup

Sketchup is found to be lacking when it comes to complex models that require a lot of initial data. It is not suited for manipulating large, complex terrains - they slow down the performance and modifying large surfaces requires extensive manual work. Importing complex 3D models of street furniture, playground equipment or vegetation can also cause some performance issues.

However, Sketchup functions well when it is used as a stand-alone software using the features and 3D models native to Sketchup. Instead of importing a terrain, the Google Earth terrain can be used - with lower resolution. Instead of using complex vegetation 3D models, the 2D face-me objects from Sketchup Warehouse can be used. Sketchup has low system requirements and is optimized for 3D models that have low complexity. If you do not have the most high-end computer and intend to create very simple 3D models, Sketchup is a good starting point. However for more complex models or advanced functions (like volume calculations) software such as Civil 3D, Revit or Rhino should be considered.

To Sketchup's benefit it must be mentioned that the Pro version allows importing and exporting DWGs. Sketchup has simple and efficient section tools that can also show the background objects, so Sketchup can be used to create accurate 2D drawings. Visually, the ability to walk on the surface of the 3D model provides higher immersion, although the visualization quality of the perspective view is mediocre. Technically the walk mode is more advanced in Sketchup than the other software in this study.

Infraworks

Unlike Sketchup, Infraworks has high system requirements and can run even complex models smoothly. Infraworks is specifically meant for importing almost any filetype into the 3D model. The import process itself can be slow and may not always work perfectly, but once the import has been succesful, the 3D model can be displayed without performance issues.

Infraworks is similar to Sketchup in that not very complex 3D modeling can be done inside the software. In fact Infraworks has even less basic 3D modeling capabilities than Sketchup. This is because most of the 3D models are supposed to be imported from other software. However, like Sketchup, it is intuitive and easy to use even for beginners in 3D modeling.

The 3D models in Infraworks are displayed with real-time rendering, meaning that during the modeling process it has the highest visual quality of all the software included in this comparison. This can be a very attractive feature for beginners and professionals alike. The visualization is the main reason that Infraworks is used.

Infraworks is not a good stand-alone software for landscape architects. Because additional 3D modeling software are required to get the most out of it, it may not be the best choice for small offices with a limited budget. One of the biggest caveats of Infraworks is that it cannot produce usable 2D drawings. The ability to produce 2D CAD drawings is a very important feature for a stand-alone software. The sole purpose of Infraworks is to create an impressive and immersive 3D visualization - and that is what it excels at.

The Infraworks model is supposed to be the end product - a visualization. This is why the Infraworks model can only be exported in one file format. Infraworks can be compared to some game engines that are also used for visualization purposes only, like Unreal Engine - which also has real-time visualization. They are typically hard to utilize as part of the design process, fitting rather at the end of it.

Civil 3D

Civil 3D and Infraworks can be said to be complementary software in some ways. This is mainly because the area where Civil 3D lacks the most is the visualization department. And that is the area where Infraworks excels at.

Otherwise Civil 3D is a good, well-rounded software for landscape architects. Most landscape architects in Finland use AutoCAD for their 2D CAD drawings. Civil 3D is based on AutoCAD, so it uses the same DWG file format and has all the same commands available as basic AutoCAD. However, it must be noted that Civil 3D is a separate software from AutoCAD - not merely an extension. But it can be used to create 2D DWGs just as well as AutoCAD. In fact I do not see any reason why an AutoCAD subscription could not be replaced with Civil 3D. It has all the same functions landscape architects use in AutoCAD, but with added 3D modeling abilities.

However, unlike Sketchup and Infraworks, Civil 3D is not the most friendly software for beginners. Those that already have experience with AutoCAD will have an advantage. Even then, the interface can be confusing to navigate at first. But with proper guidance the most important functions can be found quickly. It is important to note that a landscape architect will never use the vast majority of features in Civil 3D - so spending dozens of hours learning all of Civil 3D would be a waste of time.

Modeling in Civil 3D is best suited for the purpose of calculations, such as volumes of mass excavations and slopes of surfaces. It also provides a basis for creating accurate sections from the terrain.

It must be noted that the 3D models in Civil 3D are most often viewed in plan view. The terrain 3D model can be set to be displayed as contours. This means that usually bringing in 3D models of vegetation or street furniture is unnecessary, as they are only relevant in perspective view. Importing unnecessary 3D models should be avoided, because they can cause performance issues in Civil 3D. To avoid performance issues, only small parts of the 3D model are usually viewed in perspective using the Object Viewer - which does not allow the manipulation of the 3D model simultaneously.

Civil 3D can create DWG sections but cannot display objects in the background. The sections are mainly used to get the shape of the terrain. Other details, such as trees and furniture, are drawn in afterwards. Thus creating a section in Civil 3D usually involves a lot of manual work even when a 3D model is available. Taking into account the time it takes to set up the 3D model, it is not much faster to create a section in Civil 3D than it would be to do it manually using contours. However, with a larger number of sections there is some benefit.

Revit

In this comparison, Revit is the best software at creating and managing 2D drawings in the 3D model. The section tools are simple and show the background objects as well - and then can be exported as DWG. If the 3D model is accurate, creating a finished section does not require a lot of extra manual work.

Unlike Civil 3D, the 3D model can easily be viewed and manipulated in perspective. Vewing and manipulating the 3D model can be done in plan view as well. Plans, sections and perspective views are automatically saved and organized in a list and navigating between them is simple - this is how Revit differs from all the other software in the comparison.

The main benefit of Revit as compared to the other software is that it can create files in a BIM format without extra work - as IFC files. The lack of a coordinate system library can be considered a deficit, but this depends on the nature of the project.

A main negative side of Revit for landscape architecture is the lack of terrain modification tools. When using contours to make a new terrain is insufficient, the only other option is to modify the terrain vertex-by-vertex, which is an inefficient process. Note that Revit has an extension called Site designer that may make up for the lack of terrain modification tools in the standard version of Revit.

Rhino

Rhino is a good software for universal 3D modeling. Because of its universal nature, it has high compatibility with many other software, which is reflected in the amount of importable file formats. In this way it is comparable to other classic 3D modeling software such as 3DS Max. It has a wide variety of tools for 3D modeling, which allows for better workflows than the vertex-by-vertex type of terrain modification in Revit or Sketchup.

Unlike the other software compared in this study, the 3D modeling in Rhino is based on curves rather than polygons. This brings out some benefits - namely that the contours produced from a surface are smooth rather than jagged. But it has its downsides as well. A surface created from contours can have unintended mounds and hills due to the way the NURBS surface is calculated. When contours are used as a basis for the terrain, the accuracy suffers.

Other downsides of Rhino are the lack of coordinate systems and difficulty of creating more than basic sections. Rhino also does not display the height of an object from 0-level in the properties panel unlike Civil 3D and Revit. Clearly in product design, which Rhino is originally intended for, these are not important features.

Many things are possible to do in Rhino - but some of them may be terribly inefficient compared to other software. For example both Revit and Sketchup have a section tool that takes a couple of clicks at most - and can show the background objects. In Rhino a section without background objects is already slightly more complex to do - but showing the background objects as well is a process with several steps. If you are used to making sections in Sketchup or Revit, this method seems unnecessarily complex.

There are also some things that are possible by using Grasshopper scripts - however, scripting is clearly not for everyone and should not be expected of everyone who wants to get into modeling landscape architecture. Some of the features that are possible in Rhino only by Grasshopper scripts are already standard features in other software.

Rhino clearly has many capabilities, but some of the capabilities are too difficult to access for someone who is interested in more basic 3D modeling. It is not a good software for impatient people, as some seemingly simple things may take more time and effort than expected.

However, if you are just using Rhino to create a 3D object and import it into some other software that is efficient at making sections etc. it can be a useful part of the workflow. This is the kind of modeling it was made for. Trying to use it in ways that it was never built for will cause unforeseeable difficulties.

It must be noted though, that Rhino has an extension called Lands Design that is in Beta stage. As it is geared towards landscape designers, it has the potential to make up for some of the deficits listed here.

5.3.2. How to choose a suitable software

Which profession the software was originally built for has the highest influence on which features it has. Therefore when choosing the most suitable software, the intended profession should be considered - and it's relation to 3D modeling tasks in landscape architecture. In this regard a software built specifically for landscape architecture would have clear advantages over any of the software included in this study. No such software is currently available - however, Revit and Rhino have plug-ins geared towards landscape and site design. Plug-ins like these have the potential to improve the usability of the base software for landscape architects. The improvements that these plug-ins allow will be considered later in the conclusions chapter.

When it comes to choosing a software, the license costs and hardware requirements must be taken into account. For a cost-benefit analysis, some relevant attributes of the compared software are listed in the following chapters. It is relevant to consider the processing speed and the efficiency of the general workflow in the software, as these will largely influence the number of hours required for a modeling task - directly affecting the costs based on hourly pay.

It must be noted there are several other 3D modeling software that could potentially be used in landscape architecture that were not included in this comparison. Some are shown in the map below, which is categorised by relevant software attributes.

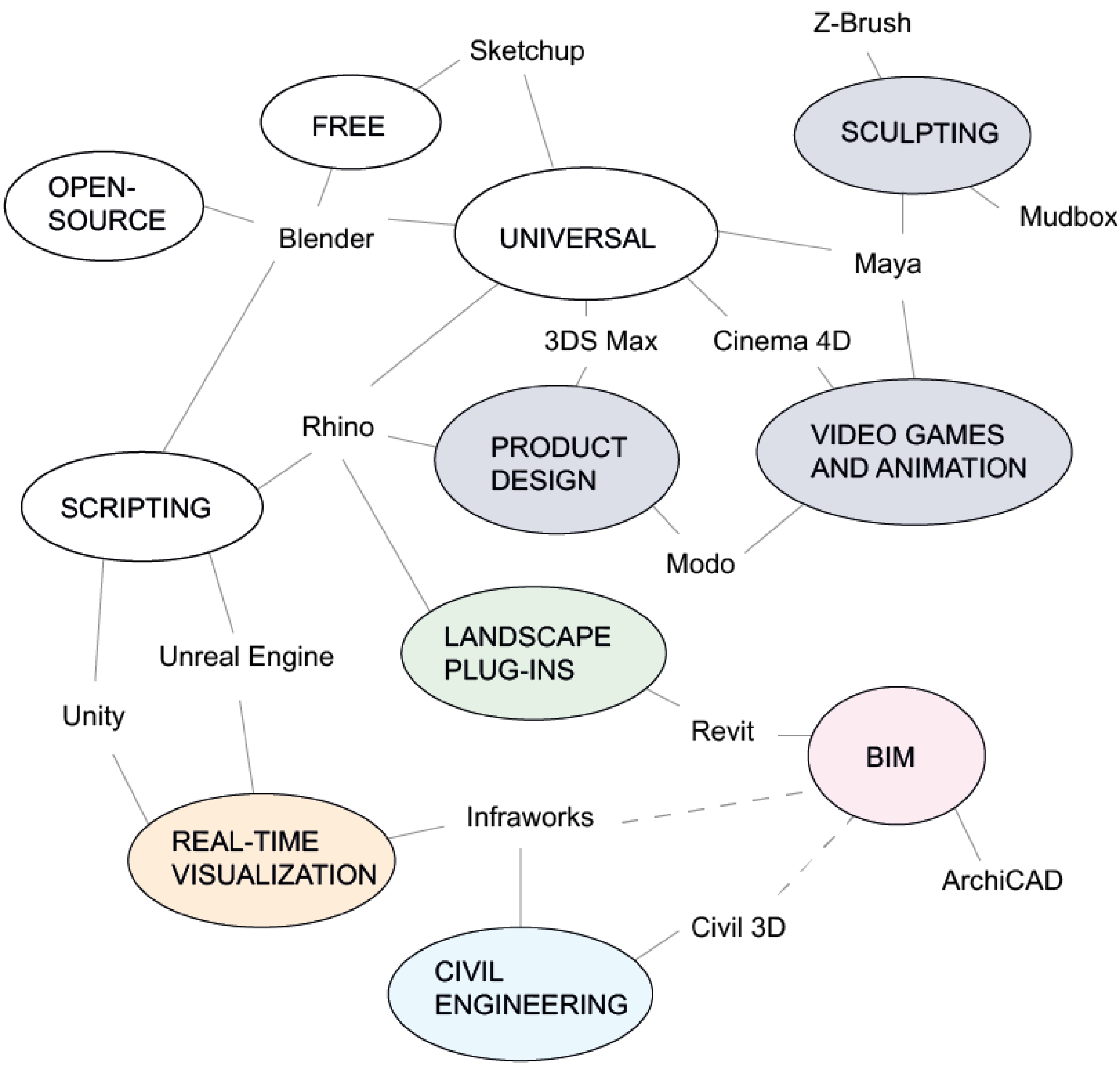


Figure 8. Software categorization by target audience.

Civil 3D 2019

Profession

Civil engineering

Costs

2 904,00 € / year
free student license

System requirements

Operating system	Microsoft® Windows® 10, 8.1, 7 SP1
CPU / Processor	Minimum: 2.5–2.9 GHz or faster processor Recommended: 3+ GHz or faster processor
Memory	Minimum: 8 GB Recommended: 16 GB
Display card	Minimum: 1 GB GPU with 29 GB/s Bandwidth and DirectX 11 compliant Recommended: 4 GB GPU with 106 GB/s Band-width and DirectX 11 compliant
Disk space	10.0 GB

Type

3D modeling, polygonal

Best suited for

- modeling in a coordinate system
- making use of Maanmittauslaitos terrain models
- plan-drawing based 3D modeling
- calculations and anaylsis

Deficits

- bad immersion level due to low visual quality
- bad perspective view modes
- not for visualisation purposes - adding 3D models of vegetation and furniture slows 3D model too much
- slow processing speeds with complex models

Efficiency

- Slow processing speeds negatively impact efficiency
- Sections cannot show background objects, requiring manual work
- Volume calculations are simple and efficient

Infraworks 2019

Profession
Infrastructure and city planning

Costs
2 178,00 € / year
free student license

System requirements

Operating system	Microsoft® Windows® 10, 8.1, 7 64-bit Professional, Ultimate, or Enterprise edition
CPU / Processor	Dual-core Intel® Core™2 or equivalent AMD processor (Quad-core Intel® Core™ i7, 6-core Intel® Xeon®, or better processor highly recommended); to use the ray traced rendering functionality, CPU must support SSE 4.1
Memory	8 GB RAM minimum (16+ GB recommended)
Display card	Any DirectX® 10.1 capable graphics card with 2 GB (or more) graphics memory, supporting 8x Antialiasing (8x AA), such as NVIDIA Quadro® 5000 or 6000 for desktops and NVIDIA Quadro 2000M or GeForce® GT 650M for laptops; (Any DirectX 10.1 capable graphics card with 1 GB graphics memory supporting 2x antialiasing (2x AA) minimum)
Disk space	16 GB

Type
Real-time visualization

Best suited for
- realistic visualization
- walking around in the 3D model gives a good idea of how the design would feel in reality
- high processing speeds even with complex models

Deficits
- limited modification of landforms
- slow importing times
- cannot create 2D CAD drawings

Efficiency
- easy to learn and use
- high processing speed during viewing the 3D model increases efficiency
- troubles with importing objects, eg. furniture can slow down the process

Revit 2019

Profession
Architecture

Costs
Revit LT (reduced features): 623,15 € / year
Revit: 3 043,15 € / year
free student license

Minimum system requirements

Operating system	Microsoft® Windows® 10, 8.1, 7 64-bit Professional, Ultimate, or Enterprise edition
CPU / Processor	Single- or Multi-Core Intel® Pentium®, Xeon®, or i-Series processor or AMD® equivalent with SSE2 technology. Highest affordable CPU speed rating recommended. Autodesk Revit software products will use multiple cores for many tasks, using up to 16 cores for near-photorealistic rendering operations.
Memory	4 GB RAM
Display card	DirectX® 11 capable graphics card with Shader Model 3
Disk space	5 GB free disk space

Type
Building information modeling
3D modeling, polygonal

Best suited for
- ease of creating 2D drawings
- good visualization level in perspective view

Deficits
- limited compatibility with file formats
- lack of terrain modification tools

Efficiency
- vertex-by-vertex terrain modification reduces efficiency

Plug-ins relevant for landscape architecture
Site designer(not included in software comparison)
- free
- does not work with Revit LT

Profession

Product design

Costs

995 € / one-time payment
195€ student license

System requirements

Operating system	Microsoft® Windows® 10, 8.1, 7 SP1
CPU / Processor	No more than 63 CPU Cores.
Memory	8 GB memory (RAM) or more is recommended.
Display card	OpenGL 4.1 capable video card is recommended. 4 GB Video RAM recommended.
Disk space	600 MB disk space.

Type

3D modeling, NURBS / curves
parametric modeling / scripting

Best suited for

- compatibility with other software
- customization - using on a personal computer that allows installation of plug-ins and add-ons is recommended
- Grasshopper is a visual scripting software that allows the creation of your own tools within Rhino - allows a lot more features but requires patience and time

Deficits

- mesh / NURBS incompatibility
- meshes do not work with all tools
- some things are only possible with Grasshopper scripts or plug-ins

Efficiency

- figuring out work-arounds for missing or deficient features takes considerable time and effort
- creating new Grasshopper scripts is extremely time-intensive

Plug-ins relevant for landscape architecture

LandsDesign (not included in software comparison)
- free while in beta

VisualARQ (not included in software comparison)
- not free
- easier architectural drawing workflows

Sketchup (Pro) 2019

Profession
Universal

Costs
Sketchup : free
Sketchup Pro: 274 € / year
student license with discount

System requirements

Lowest system requirements of the comparison.

Operating system	Microsoft® Windows® 10, 8.1, 7 64-bit Professional, Ultimate, or Enterprise edition
CPU / Processor	Minimum: 1 GHz processor Recommended: 2+ GHz processor
Memory	Minimum: 4 GB RAM Recommended: 8+ GB RAM
Display card	Minimum: 3D class video card with 512 MB of memory or higher and support for hardware acceleration. Recommended: 3D class video card with 1 GB of memory or higher and support for hardware acceleration. Please ensure that the video card driver supports OpenGL 3.0 or higher and is up to date.
Disk space	Minimum: 500B Recommended: 700MB

Type
3D modeling, polygonal

Best suited for
- creating an easy and simple 3D model
- walking on 3D model terrain gives a good idea of how the design feels in reality
- on a tight budget the free version of Sketchup can be better than nothing - however, it lacks some crucial features like importing CAD files

Deficits
- Sketchup is not recommended for handling a lot of complex data - large CAD files cause Sketchup to crash
- slow modeling speed with complex models
- lacks in more advanced features

Efficiency
- easy and fast to learn and use
- fast with simple models, however efficiency decreases as complexity increases

6. Conclusions

6.1. How to improve landscape architecture 3D modeling

Making more or better 3D models is not an end-goal in itself, rather the goal is to make better designs, and 3D modeling is just a tool for this goal. There is no need to improve the use of 3D modeling tools just for the sake of doing 3D modeling, as 2D drawings and physical models are both a valid method of design. Other methods do not need to be discarded in favour of 3D models - instead it should always be considered which method is appropriate in which scenario. There are times when 2D drawings may be sufficient and more efficient than making a 3D model. The purpose of the 3D model - just like any other tool - should be considered prior to using the tool.

In the survey it was observed that the majority of Finnish landscape architects use SketchUp as the 3D modeling tool in their design process. However, in the software comparison it was observed that overall, SketchUp is not the best tool in the market for 3D modeling landscapes currently. This doesn't mean that landscape architects need to move onto better 3D modeling tools. What it does mean is that the purpose of the 3D model needs to be considered, because this purpose defines which software to use. The areas that each compared software is good at and weak at are outlined in the reflections of the software comparison.

Without experience in using several 3D modeling software, the best use cases and limitations of each software can hardly be considered - therefore making it difficult to determine which software to use from the start. As the first 3D modeling software, Sketchup is not a bad choice due to the software being free to use and having an easy learning curve. However, after learning everything that Sketchup has to offer, the limitations of the software start to become apparent. If more features are desired, Civil 3D, Rhino, Revit (or ArchiCAD) can be considered - as more expensive alternatives. It must be noted that excelling at 3D modeling in SketchUp does not necessarily mean that this skill will transfer to more complex software. It may become a hindrance when a similar feature in another software ends up working in a different way. Expecting all 3D modeling software to work the same way as SketchUp can lead to disappointments.

Therefore if you are already good at SketchUp, do not expect all your problems to go away by switching to another software, as you will run into other problems instead. There is always a trade-off, since no software is perfect for the purpose of 3D modeling landscape architecture. By reading the software comparison in this thesis, you should be able to get a good idea of which problems you will run into in each software.

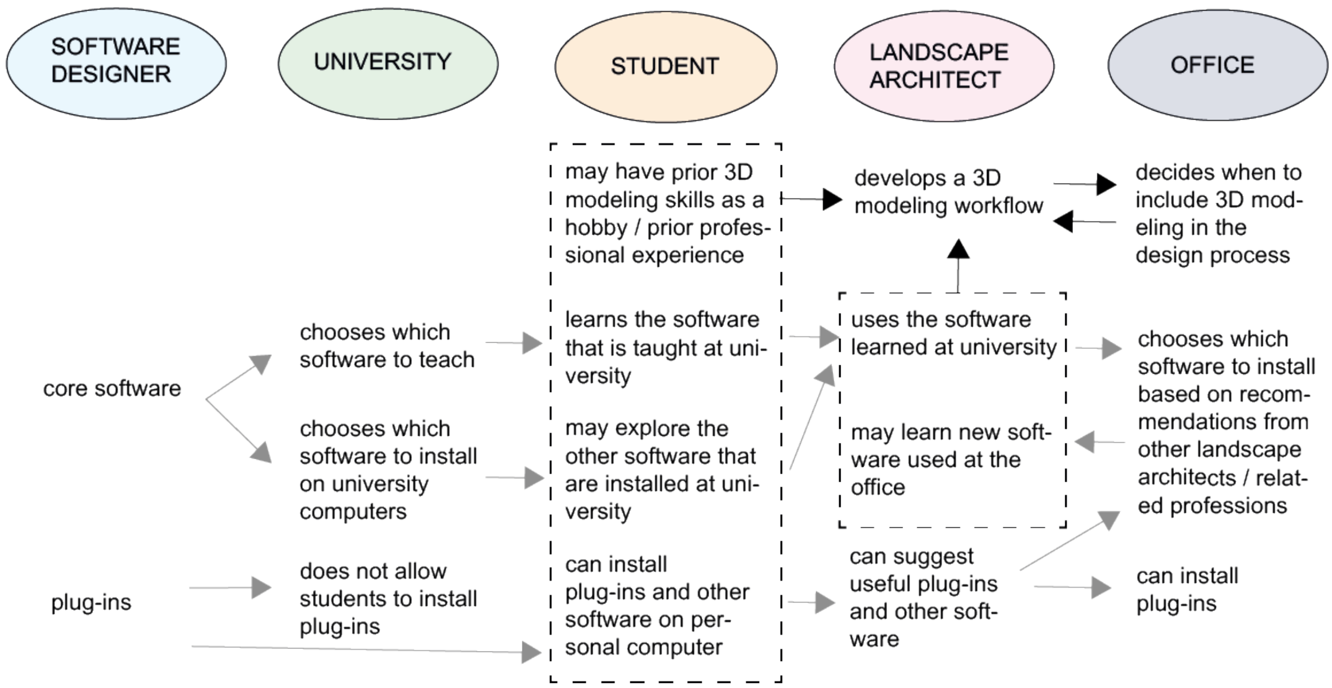


Figure 9. Roles in landscape architecture 3D modeling.

The next chapter will talk about the roles of improving landscape architecture 3D modeling, pictured above.

6.1.1. Roles

Based on the literature review, it is evident that there are a lot of different parties involved in improving use of 3D modeling and landscape information models in landscape architecture. These parties have differing roles in the development. For example, “Integrating BIM Technology into Landscape Architecture” (Sipes, 2014) is written from an industry perspective by the American Society of Landscape Architects and mainly focuses on data exchange between software. “A 3D landscape information model” Gill, 2013) is written from a software development perspective.

With the help of these sources and considering what has been learning in the course of the survey and the software comparison, the following list of what each party can do to improve 3D modeling and LIM has been compiled:

landscape architect (including students)	● educating themselves on how to use 3D modeling software ● tweaking existing software with found plug-ins, scripts etc. ● customizing existing tools eg. starting with an existing model template, then modifying it to suit landscape architecture ● creating scripts and tools as add-ons to existing software and distributing these to non-coding landscape architects ● directing the development of landscape plug-ins
landscape architecture university	● funding and supporting research of 3D modeling tools ● gathering feedback from students on the usability of tools: how easy it was to learn and use, how helpful it was, etc. ● defining the main 3D modeling software future landscape architects should learn and allocating funds to teaching this software ● ensuring the appropriate 3D modeling software for landscape architecture are installed ● having a professional make sure that all necessary features were included in software installation - such as the object families and Site designer in Revit ● making it easier to install landscape-related plug-ins or including the plug-ins in the installation package ● a test work station where anything can be freely installed to ensure nothing is missing from the university-wide installation packages - and to test new software and plug-ins before adding them to the curriculum
landscape architecture office	● investing in software that fits the needs of the office ● investing in education and professionals who can use the software ● considering how to better include 3D modeling in the workflow
landscape architecture associations	● developing information exchange standards ● funding and supporting research and development ● gathering information from professionals on which software they use and how successfully
software firms	● improving interoperability of software ● developing add-ons or new features into existing software ● developing a separate LIM (Landscape Information Model) software

Figure 10. Roles in landscape architecture 3D modeling (2).

Landscape architect

The most important thing that can be done on an individual level is educating oneself on how to do 3D modeling. Knowing how to learn and use resources is a skill in itself. When learning how to use a new 3D modeling software, previous 3D modeling experience is helpful as knowing the keywords to search for makes searching for new information more efficient. However, it must taken into account that many software use different terminology for what is essentially the same thing. This is why basing your search on one keyword is not always reliable. Making use of official software manuals can alleviate this problem. Note that some software manuals can be found with the keyword “help” or “guide” instead.

Another thing that can be done on an individual level is investing in a personal computer that is able to run the software you want, especially if you are a student, as the computers at university do not currently allow the installation of plug-ins. Some software run the potential to be hugely improved by the installation of plug-ins and add-ons. Until the situation at university is improved, those that have their own computer are at an advantage. With a student license you can also install Civil 3D and Infraworks on your own computer for free, as well as some other, additional software that are not currently installed at university computers. The current installation of Revit at Aalto lacks the family libraries that would include street furniture and trees.

University

As the only university teaching landscape architecture in Finland, Aalto University plays a large role in the 3D modeling skills of future landscape architects. As is evident from the results of the survey, Sketchup and Rhino are currently the most widely used 3D modeling software by Finnish landscape architects. When the author started studying landscape architecture in 2011, the software being taught at Aalto was Sketchup. Since 2015 new landscape architects have been taught how to use Rhino 3D, the author being one of the teachers. It is no coincidence that these are the software most landscape architects are using today. This is why it is important for Aalto to consider which software are being taught, as that defines the main 3D modeling software used by future generations of landscape architects.

At Aalto there are several 3D modeling software installed. As not every student can afford a high-end 3D modeling computer, it is understandable for students to want to make use of the software that are already available. At the moment of writing, these software are Rhino 3D, Revit, ArchiCAD, Sketchup Pro, Maya, 3DS Max and Blender.

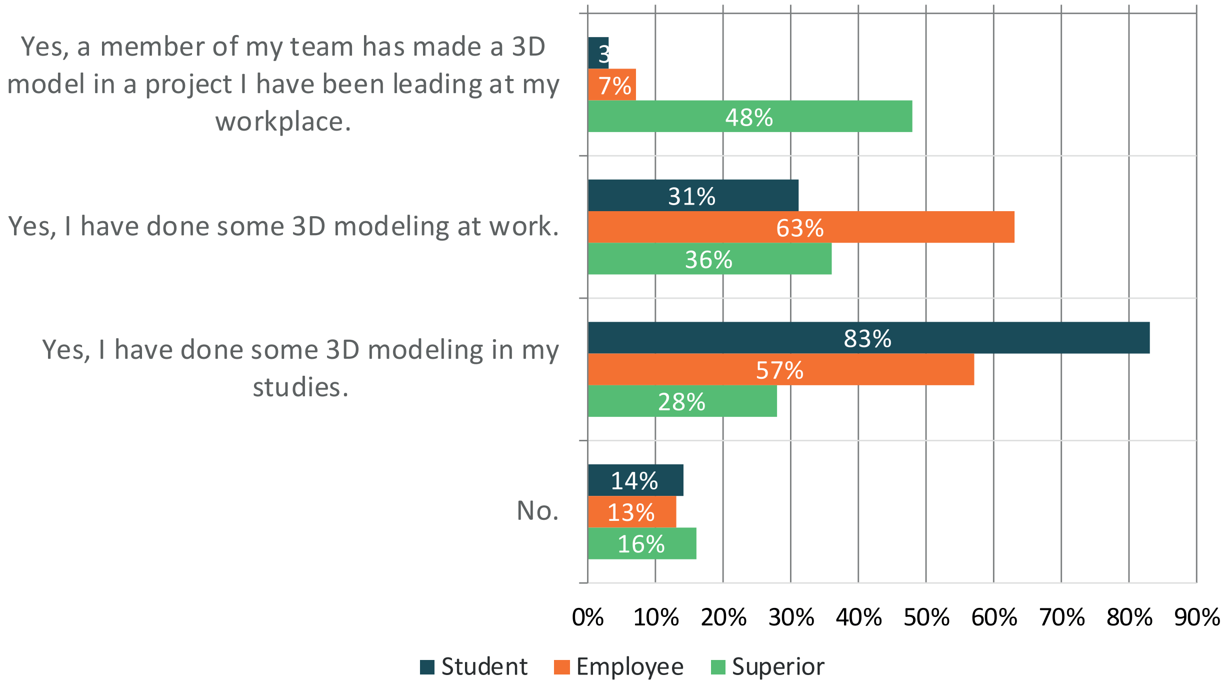
However, as can be seen from the results of the survey, these are not the only software that landscape architecture offices use. Some other ones used were Civil 3D and Infraworks, which are included in the software comparison. Another that was mentioned was Cinema 4D. To ensure that the software skills of landscape architecture students are relevant and up-to-date, it should be considered if some of these software should be installed on university computers or included in the software teaching curriculum.

Of the software that is already in use in university, it should be ensured that landscape architects are taken into account in the installation process. The current installation of Revit is missing useful landscape features: tree “families” (which can be included in the installation for free) and the Site designer plug-in, which can be downloaded from the Autodesk website for free. These features do not come with any additional license costs, it is only a matter of including them in the software installation package. When there is no knowledgeable landscape architect supervising the software installation, it is understandable that these features can be missed.

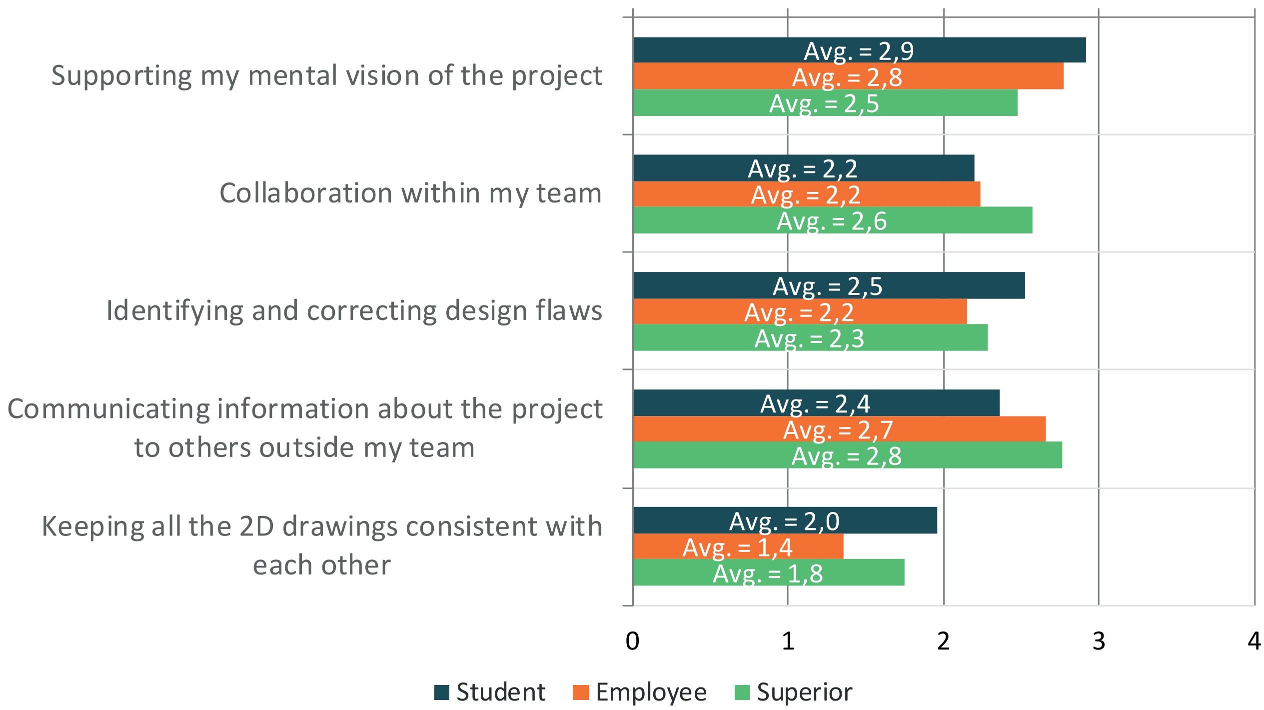
What could be done is that there would be a work station where software can be freely installed and tested by landscape architecture IT teachers. This way it could be ensured that the most beneficial features for landscape architects are taken into account. If there is something missing from the university’s installation package, the IT teacher could notify the software department of this.

Landscape architecture office

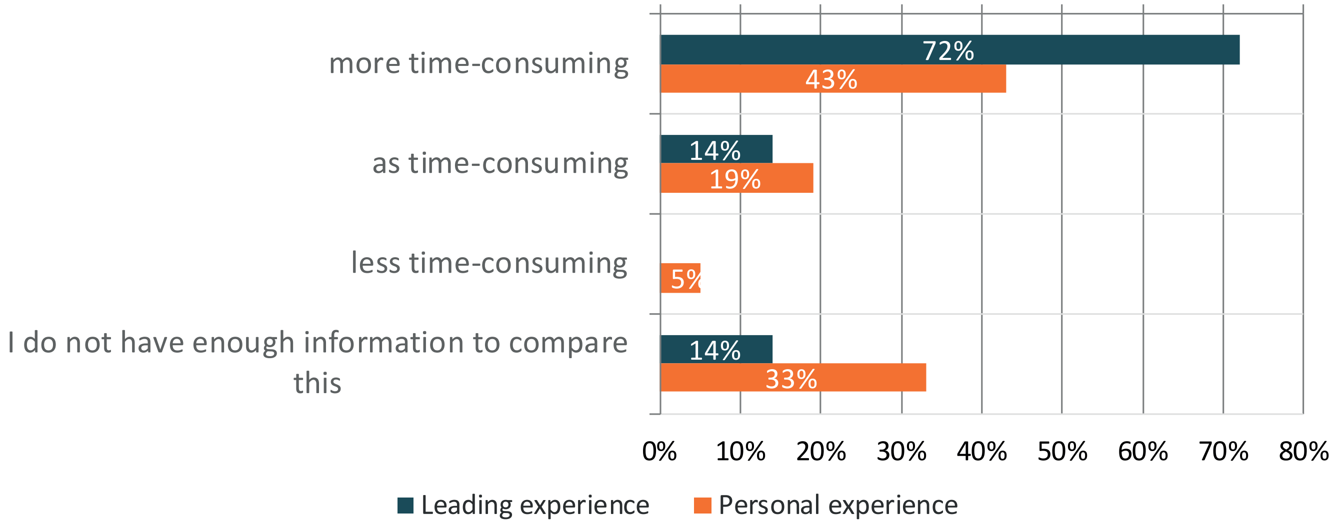
Although it is usually the younger landscape architects that are more knowledgeable in 3D modeling, it is also important for the decision-makers to have some awareness of the workings of 3D modeling. In the survey, of those in a leading position (project leader or supervisor) only 36% had personally done 3D modeling at work and only 28% had done 3D modeling during studies. This is compared to employees, of whom 63% had done 3D modeling at work and 57% during studies; and students, of whom 83% had done 3D modeling during studies.



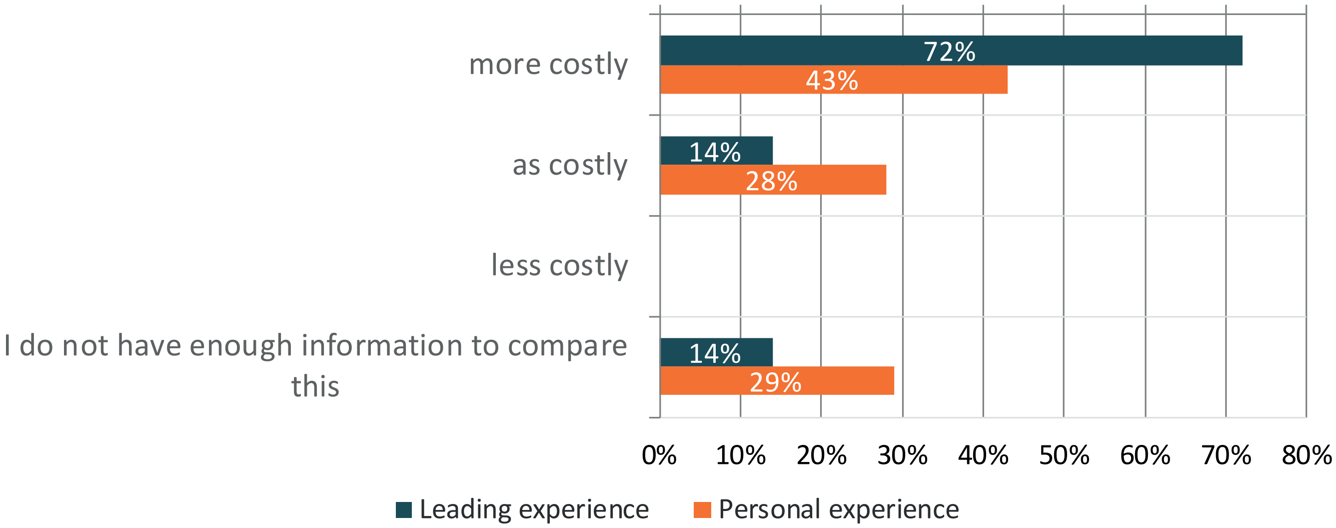
It can be considered somewhat concerning that those that lead projects where 3D modeling is done, have the least experience with making 3D models themselves. The experience of leading projects does seem to give some idea of what 3D modeling is capable of, since the benefits experienced from 3D modeling did not differ greatly from the overall results in the survey, as is shown in the graph below.



However, those in a leadership position were the only ones to reply in the free-word section of the survey that demands from the client were an important reason to do 3D modeling. They also were the most certain of all groups that projects with more 3D modeling were more time-consuming:



It seems that for some superiors the underlying attitude is that 3D modeling is so time-consuming that it will be done only if specifically requested by clients - instead of considering themselves whether to suggest it to the client. This may be a result of the lack of experience in making 3D models themselves. However, superiors do agree that 3D modeling has benefits - rather they may think the cost does not always justify the benefit. Those leading a project were far more likely to consider 3D modeling more costly than those with personal experience with 3D modeling.



It can be considered that for landscape architecture offices it is not enough that the 3D model provides benefits - but also that the modeling process would be as fast and efficient as possible, so as to avoid increasing the costs of the design process. However, due to the lack of experience leaders have with 3D modeling software, it would be hard for them to determine what are the differences of efficiency between different software. The results of the software comparison should provide some direction on this.

Landscape architecture offices would benefit from improvements in software that make the 3D modeling process more efficient. However, what they can do at the present time is hire people who are knowledgeable about 3D modeling and can provide suggestions on how a 3D model could be used more efficiently as part of the design process.

Software designers

The creators of 3D modeling software are the most important party to consider in improving landscape architecture 3D modeling. They are the ones that have defined the features of current software - taking into consideration the needs of their target audience. It is this pre-defined target audience that largely defines the possibilities and limitations of a software.

As consumers what landscape architects can do is consider the needs of the target audience and how well these match with the needs of landscape architecture when choosing the software to use. What software designers can do is include landscape architects in the target audience and ask their opinions on what features they need in a 3D modeling tool. Considering the needs of landscape architects is easier if the software designers also have experience with landscape design, as is the case with the developers of the LandsDesign plug-in for Rhino. The results of this software comparison can also be used to guide software developers - however, it must be accounted for that the results are relative to the other software used in the comparison. A software having a perfect score in a task does not mean that its perfomance in said task could not be in any way improved in the future. It simply means that it is one the best currently available options.

Plug-ins such as LandsDesign are another way to address the needs of landscape architects. When a software already exists that is used in landscape architecture, but might need minor improvements, this is one possibility. However, it can be considered that improving the core software is generally better - since plug-ins tend to pose their own problems. The benefits and limitations of plug-ins are considered in the following chapter using LandsDesign for Rhino and Site Designer for Revit as example.

Plug-ins

According to the document "Integrating BIM Technology into Landscape Architecture"(Sipes, 2014) the short-term needs of landscape architecture can best be met by tweaking existing software. One solution to this is using landscape-oriented plug-ins made for existing 3D modeling software. Two such plug-ins are LandsDesign for Rhino and Site Designer for Revit. LandsDesign is currently in beta stage. Site designer is a free plug-in that can be downloaded from the Autodesk website. However, it does not work with Revit LT, only the full version of Revit.

This chapter looks briefly at what benefits the plug-ins may provide and what challenges they may possess in the landscape architecture design workflow. A common problem with plug-ins is that the features of the plug-in may not be fully compatible with all the other features of the main software. This is acknowledged on the Autodesk website on Site Designer for Revit:

"If you choose to use Site Designer for site design, use only Site Designer to create site elements. Do not create some site elements using Revit and other site elements using Site Designer. If you try to use both types of site elements, the toposurface can produce an inconsistent state, and errors may result. In particular, Revit-based building pads, subregions, and graded regions can cause issues. If you have already created some Revit site elements, delete them before using Site Designer. "[1]

The problem is present in LandsDesign as well. Usually compatibility works well in one direction - from the main software to the plug-in. But if you wish to use a plug-in element with the main software's tools, this may cause errors. In this brief examination of plug-ins, the backwards compatibility is considered among other factors in improving the main software.

1 Knowledge.autodesk.com. (no date). Site Designer for Revit. https://knowledge.autodesk.com/support/revit-products/learn-explore/caas/CloudHelp/cloudhelp/2019/ENU/Revit-AddIns/files/GUID-0866C35A-51D5-444E-8231-A0079EE3E4E6-htm.html Accessed 2.8.2019

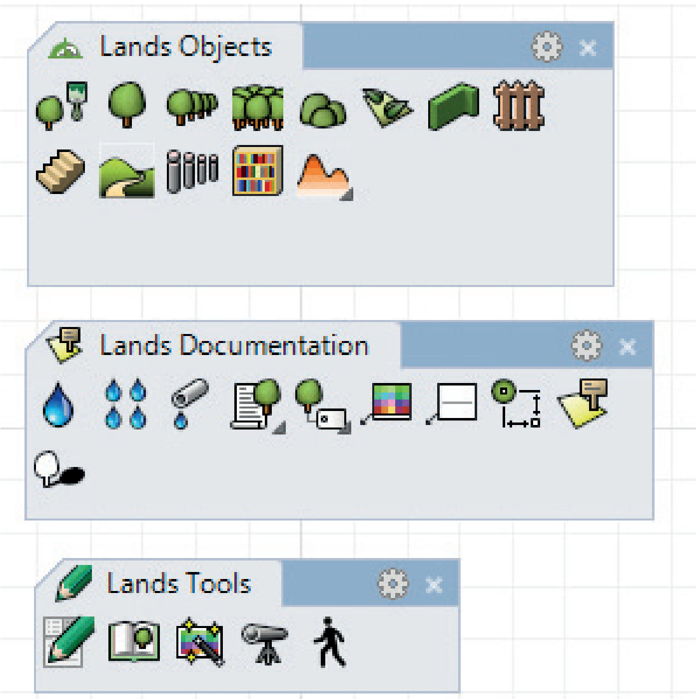
Features of LandsDesign for Rhino (Beta)

According to the results of the software comparison, Rhino was most lacking in the abilities to properly set up the 3D model with the coordinate systems in mind - and making use of the Finnish terrain models from Maanmittauslaitos efficiently and in high quality. Some inefficiencies were also found in the ability to connect different different surfaces to each other. The use of NURBS was also found to be problematic in terrain modeling due to some NURBS modeling tools causing inaccuracies in the topography when created from contours. Rhino also does not have integrated tools for water simulations. In terms of representation, better section tools and ability to virtually walk on the terrain were desired. Better integration of lighting could also be considered.

According to the LandsDesign website, LandsDesign has the following features [1] . The features that seem to be completely new when compared to the core Rhino are marked with green, and with orange features that already are present to some extent in Rhino, but are probably improved in Lands Design. The rest are features that are already present in Rhino without having to install Lands Design. It might be that these features are duplicated in the LandsDesign plug-in because the LandsDesign features are not compatible with already existing tools in Rhino.

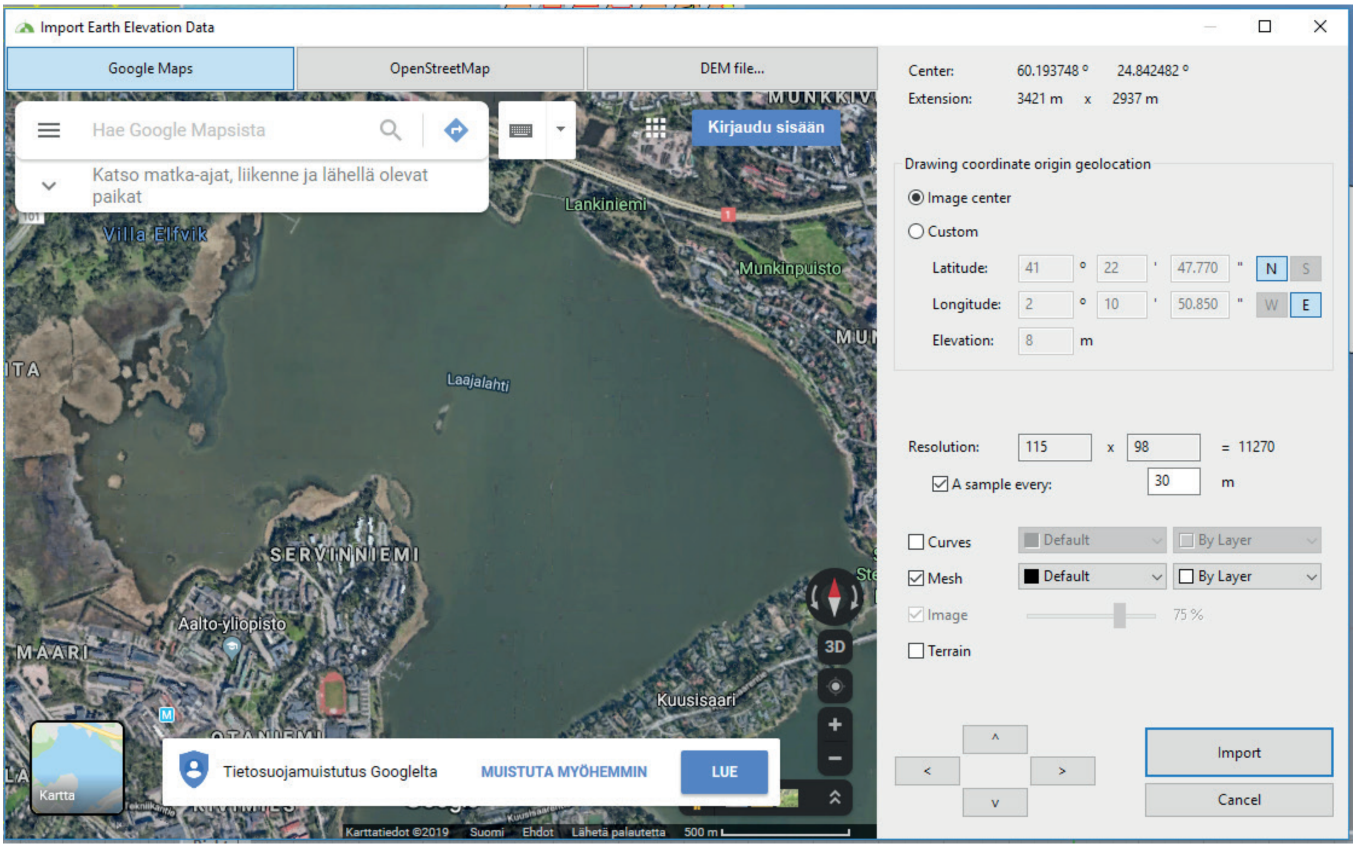
- Freeform landscape modeling
- Vegetation
- + 1800 plant species in the Plant database
- Terrain modeling tools
- Civil work elements
- Urban furniture library
- Shoot stunning Renders
- Create Virtual tours
- Documentation tools: areas, dimensions, tags, quantity takeoffs…
- Setting out plans
- Watering system tools
- 2D-3D Representation modes
- Easy editing tools
- Layer Manager
- Easy user interface
- Work in Paper/Model space
- Image filter editor
- Customizable display modes
- Plenty of CAD/Drafting tools
- AutoCAD .dwg and other file support

The features that were found to be lacking in core Rhino are of the most interest for this brief investigation - the goal is to see if LandsDesign can improve these detected flaws. The new features do not seem to completely correspond with the desired improvements, and instead include some features that were not considered in the software comparison. The full features of Lands Design are represented in icon format with the tool palettes of Lands Design below.

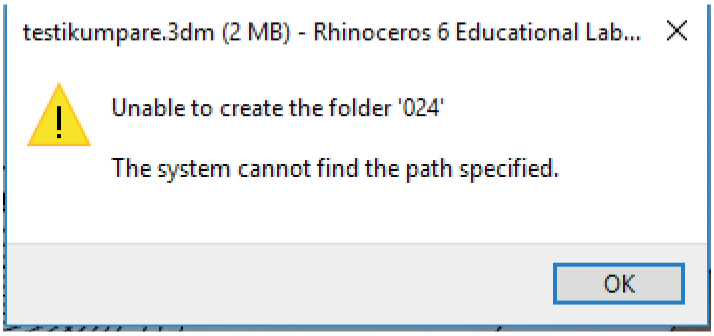


1 Lands-design.com. (no date). Features. http://www.lands-design.com/features/ Accessed 31.7.2019

Making use of Finnish terrain models

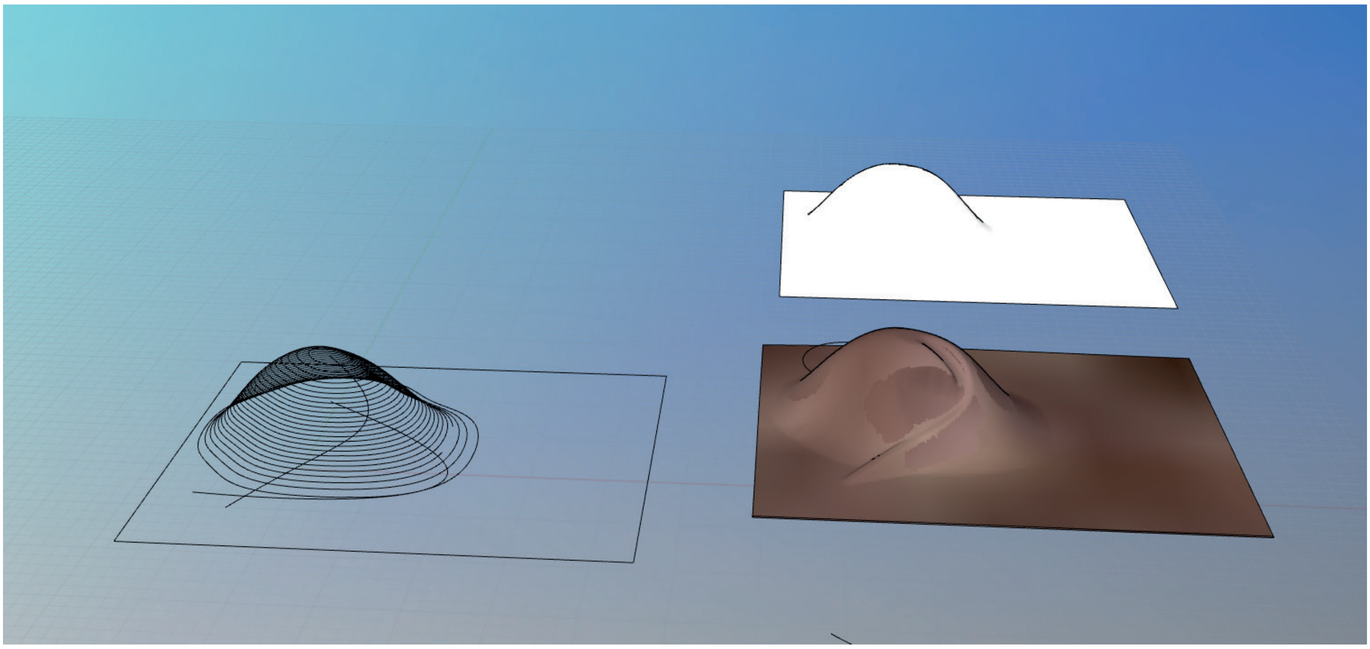


Relating to the setting up of 3D models, Lands Design was found to have a tool called “Import Earth Elevation Data”. This seems to be similar to the geolocation setup used in SketchUp - it has an option to use the Google Earth model as well. Additionally OpenStreetMap can also be used. The most relevant feature for using the terrain models from MML is the DEM file functionality, however. Unfortunately the Esri ASCII grid file format is not supported. The TIF file format is, however, the current version of Lands-Design was unable to open the GeoTIFF file formats from MML. Attempting to use the OpenStreetMap functionality also caused an error, shown below:

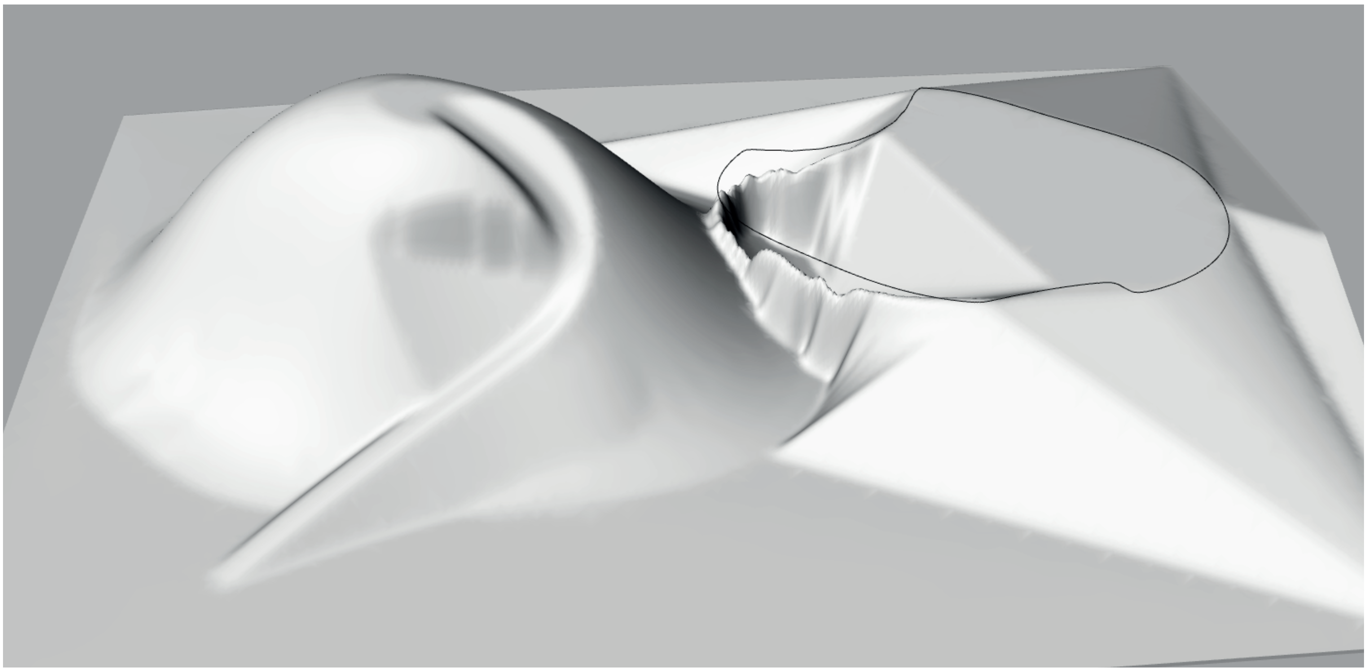


The current Beta version of Lands Design does not seem to support the use of Finnish terrain models any more than Rhino does.

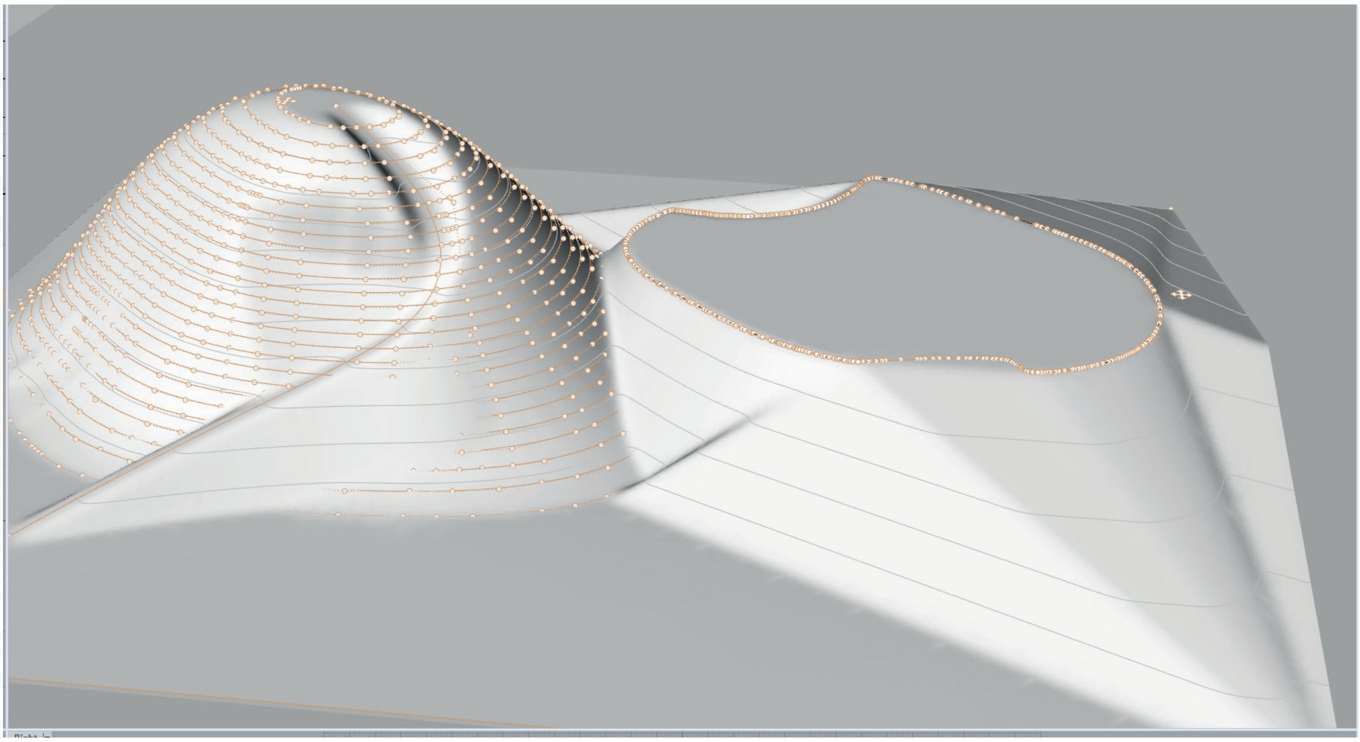
Terrain modeling



Above the white 3D model is a NURBS surface made in Rhino. From this the contours were created. These contours are used to create the LandsDesign terrain, shown in brown. The LandsDesign terrain uses a mesh instead of a NURBS surface, meaning that the inaccuracies of the NURBS will be avoided. However, only the terrain modification tools in LandsDesign can be used - these are pick boundary, add contour, add hole, add cut and fill, add path, divide, volume of earthmoving and elevate curves.



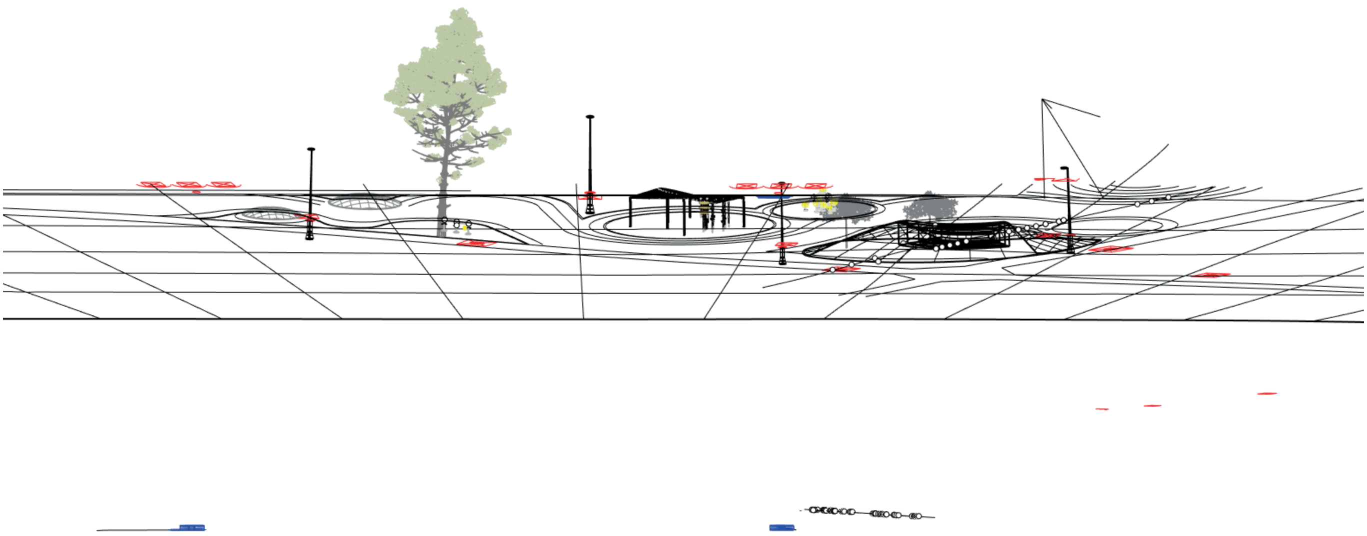
Above is shown how the “add contour” tool functions. The newly added contour is the one shown in black. It does not ignore the previously added contours, instead leaving a mound where it is overlapping with other curves. This was not the intention when creating this modification. However, add cut and fill creates a better result.



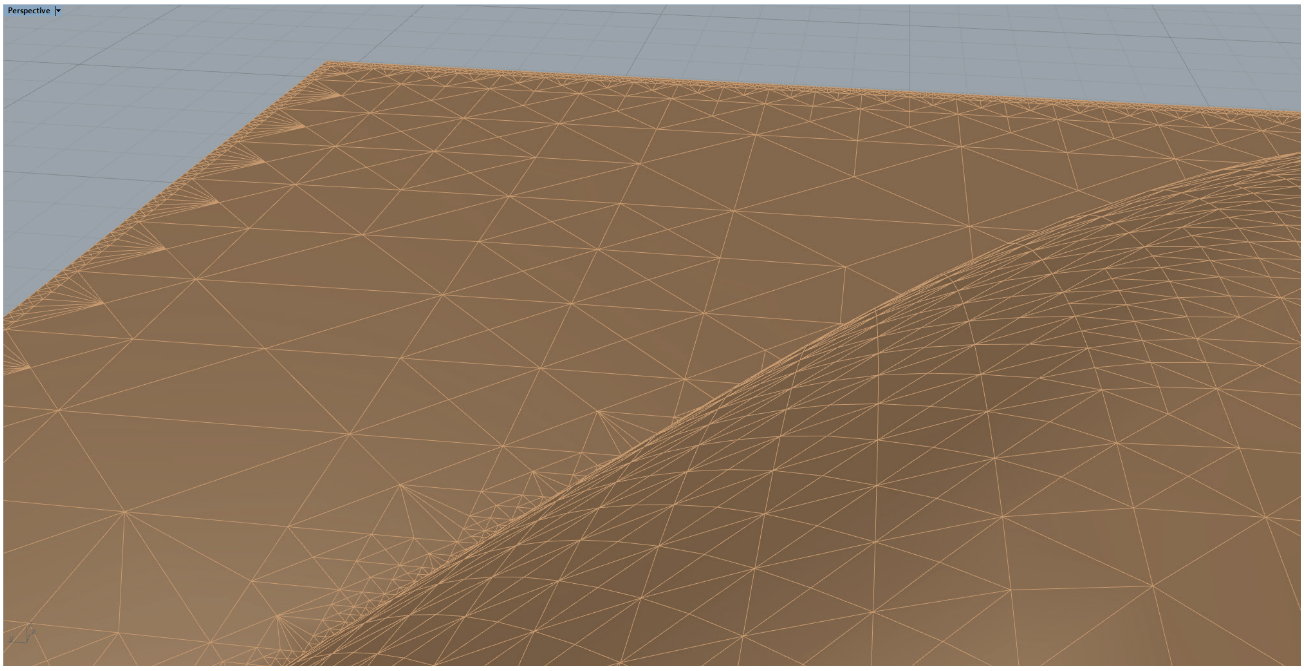
The LandsDesign terrain can be exploded into a regular mesh that works with some Rhino commands. However, to use all commands, the terrain should be converted to NURBS. The problems are similar to converting a regular mesh to a NURBS surface.

Representation

LandsDesign does not seem to include an improved section tool. There is an improved walkmode, however. When walking on a LandsDesign terrain, the movements follow along the curvature of the model, meaning you can climb the 3D modelled hill. However, it does not work with other surfaces - walking on them will cause you to fall through to the C-Plane level.



Looking at the NURBS surface from below.

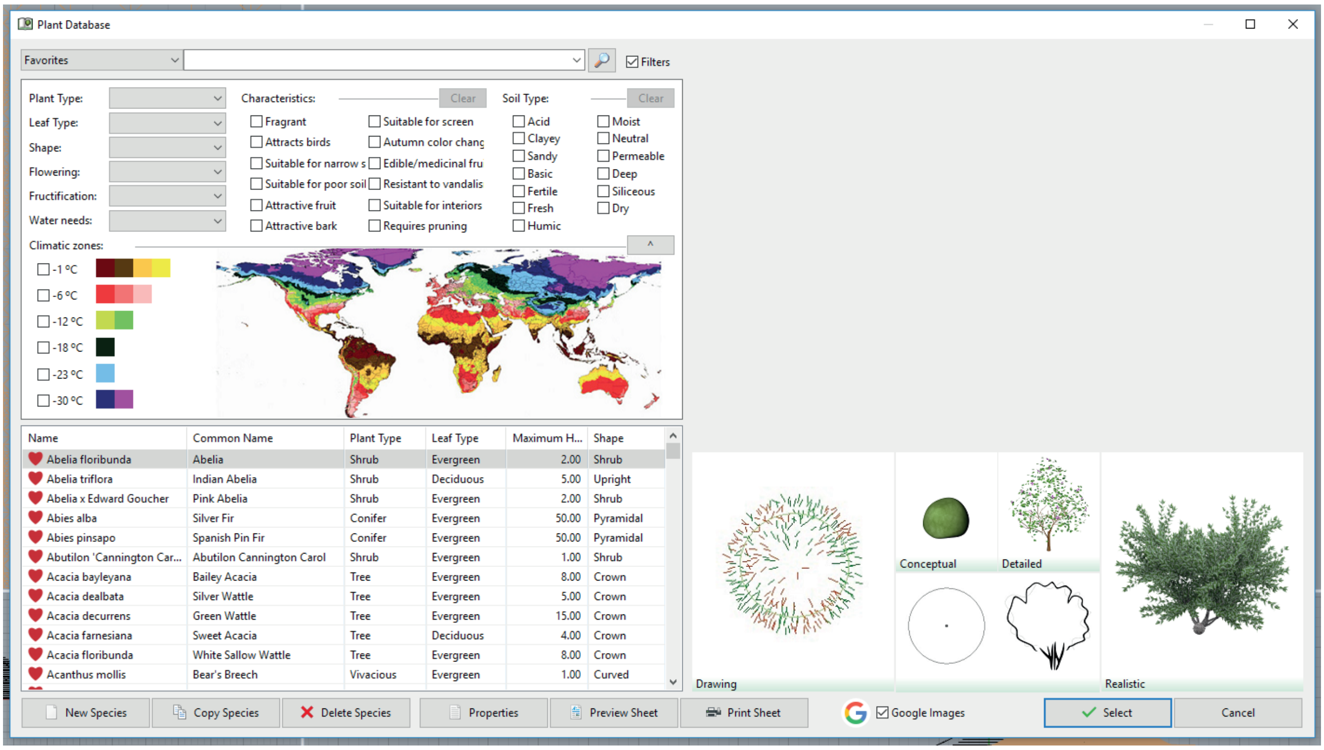


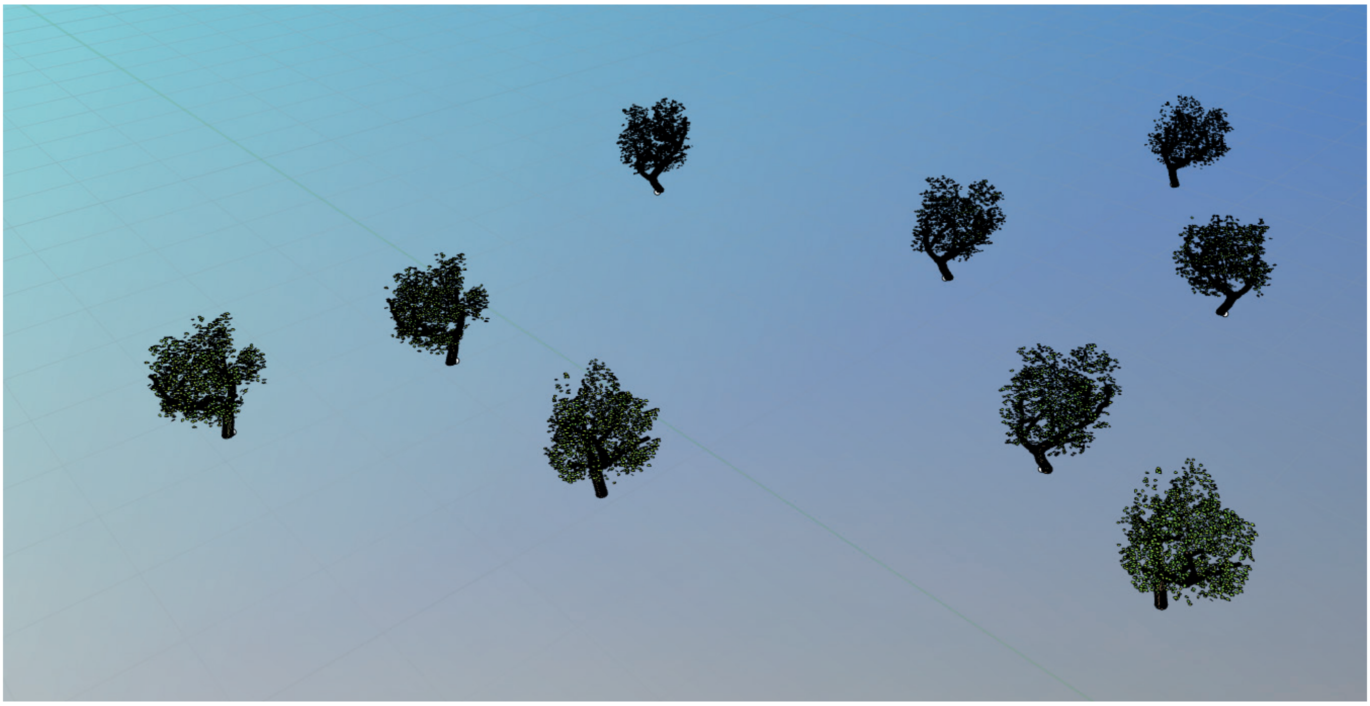
The LandsDesign terrain can be walked on. Above is shown the view from the walker's perspective.

Not found:
- water - rather than water simulations, the water tools are about placing sprinklers, which are hardly used in Finland
- lighting
- sections

Other improved functions

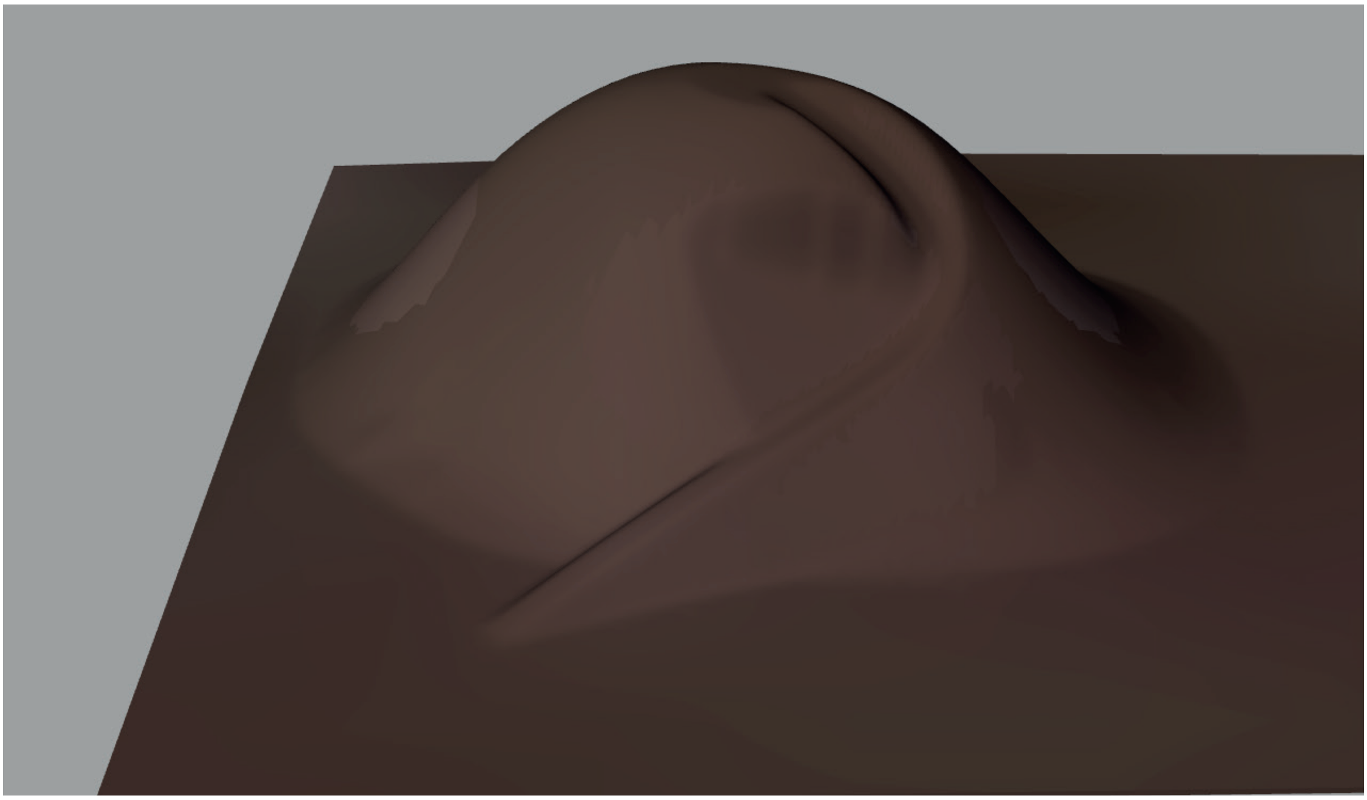
Some features of Rhino were not found to be particularly deficient compared to the other software in the study. However, the additional features presented in LandsDesign can be considered a plus. The most major one of these is the vegetation library.





LandsDesign allows you to pick from premade plants as well as creating your own. The plants can be placed in numerous ways: singular, rows, forests, shrubs and parterres.

Other new features compared to core Rhino are hedges, fences, stairs and paths. An example of a path created in LandsDesign is shown here. The path tool allows to enter the width of the path based on a centerline and the slope of the path.



How does LandsDesign raise the score of Rhino in relevant areas?

1.3. Importing the existing terrain model from Maanmittauslaitos (ASCII grid, GeoTIFF and LAZ file formats)	Can open ASC, but not ASCII grid, GeoTIFF or LAZ. However, can open ASCII grid with Grasshopper plugin. (3 pts) No improvement currently, but future improvement possible.

2.1. 3D modeling from contours	Yes, using meshes or preferrably NURBS. (5 pts)
2.2. Connecting to the existing terrain	No way to merge NURBS surface with mesh. Mesh to NURBS conversion is not always succesful. Two NURBS surfaces can be joined, but two NURBS patches will pose difficulties due to the edges not meeting. (2 pts) Cannot merge two LandsDesign terrains into one.
2.3. Resulting contours from surface • format and height values • accuracy	Yes. Can be saved in dwg format. Exported contours have height values. (5 pts) Accuracy: Contours are very smooth when created from NURBS. Contours can include unintentional mounds or hills. (3 pts) +1 contours from LandsDesign terrains are more accurate due to using meshes.

3.2. Routes	Can project as lines. Can split into separate surface for coloring. (4 pts) +1 Route tool that allows the adjustment of width and slope of path.

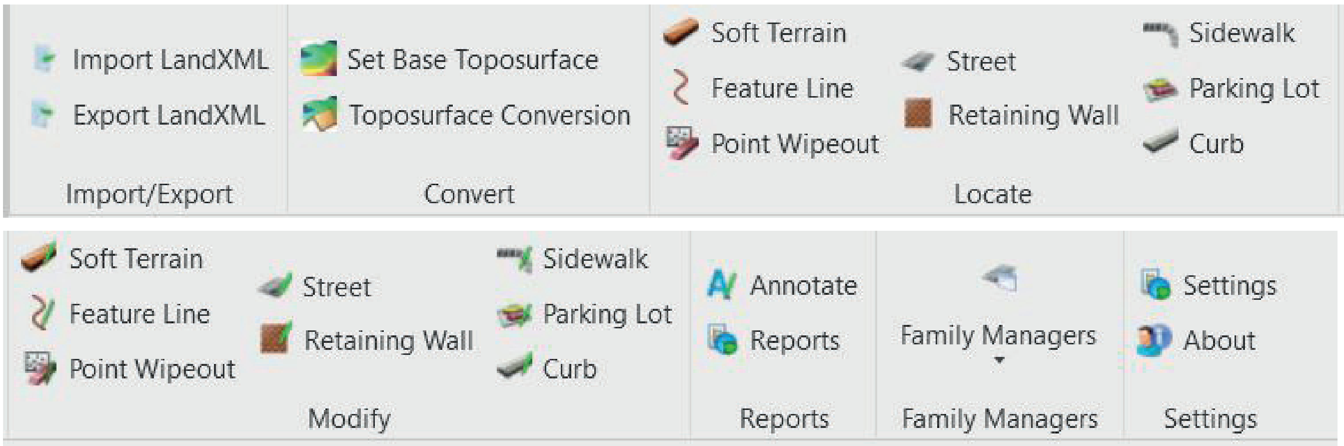
3.5. Vegetation	No problems with importing trees. The software runs smoothly with a small amount of detailed tree models. No tree library. (4 pts) +1 Tree library.

5.1. Perspective view • moving in perspective view • quality of unrendered view	Can set camera on ground level. Can walk on ground level. Does not stay on eye level while walking on sloped terrain. (3 pts) +1 Follows sloped LandsDesign terrain. Good visual quality. (4 pts)

Total score improvement: 74+4=78.

Features of Site Designer for Revit

According to the results of the software comparison, Revit was most lacking in the ability to set up the model as well as file compatibility. Revit does not have a coordinate system library and cannot use the file formats provided by MML. In terrain modeling, the biggest problem is inefficient terrain modification, and some deficiencies in exported contours. Revit does not have water simulation tools, and marking routes is inefficient. Other problems are mainly about importing files, but the walk mode could also be improved.



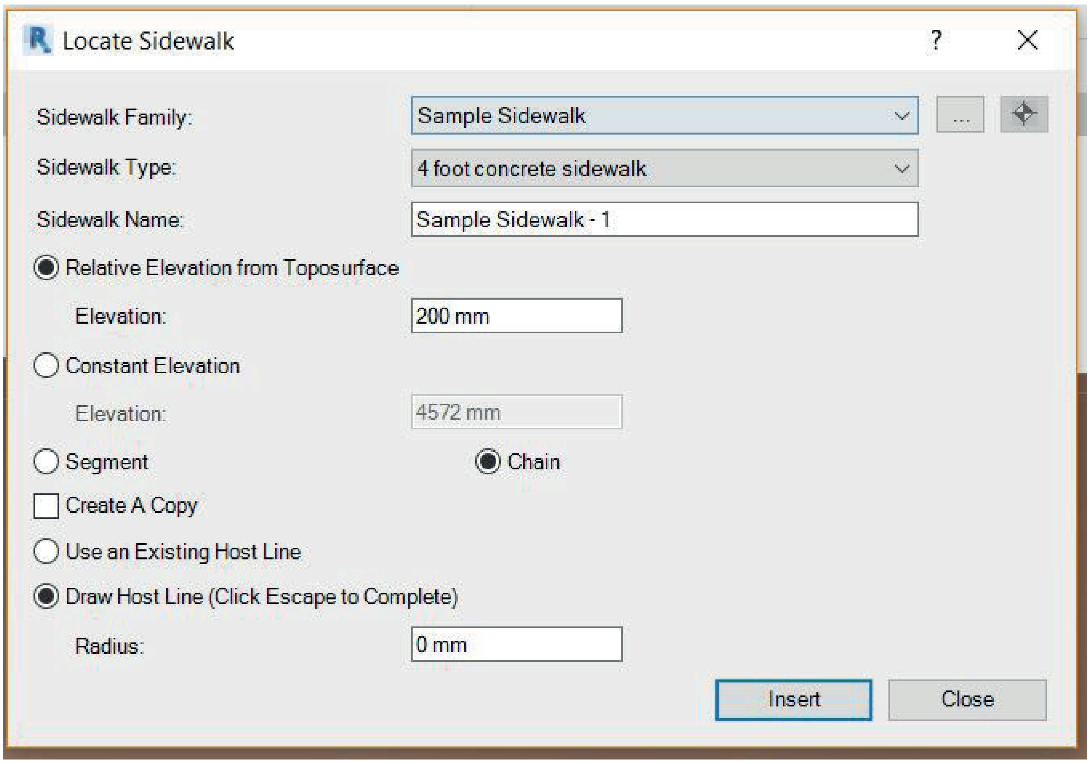
Above is shown the tool palette of the Site Designer.

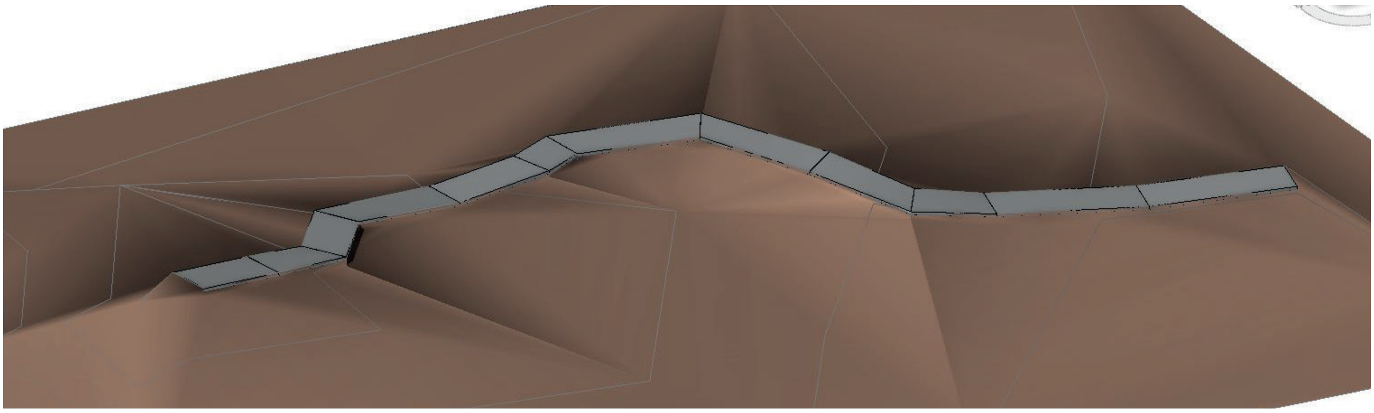
According to the Autodesk website, Site Designer allows you to complete the following tasks. [1]

- Report and schedule areas, volumes, and cut and fill volumes to better understand the impact of site design changes on requirements to move or add fill.
- Iterate conceptual designs and create more realistic visuals of the building site by incorporating grading features directly into the Revit model.
- Better communicate conceptual design ideas about the building site to engineers who can then complete the detailed site design using professional civil engineering tools like Autodesk Civil 3D.
- Share the appearance of site plan designs for better communication with everyone involved in the project, including owners, architects, designers, planners, and civil engineering firms.
- Share a site model between Revit and Civil 3D through LandXML files, improving collaboration between architects and engineers working on a project.
- More quickly add design elements to your site such as berms and drainage swales, minimizing the time required to mass grade a site and to try alternatives at the design development stage.
- Use special terrain families within Site Designer to define parameters that control widths, cut and fill slopes, and other projection settings.
- Locate hardscape components such as streets, intersections, sidewalks, curbs and walls that can follow the existing terrain and have controlled elevations and slopes - all while the toposurface is automatically maintained.

1 Knowledge.autodesk.com. (no date). About Site Designer. https://knowledge.autodesk.com/support/revit-products/learn-explore/caas/CloudHelp/cloudhelp/2019/ENU/Revit-AddIns/files/GUID-C0478C24-AED4-431F-8782-83F1C7AE4A39-htm.html Accessed 1.8.2019

Based on the description of site designer, it seems to have some new tools for terrain modification, with mostly street design in mind. But these can also be applied to landscape architecture. Especially the side-walk tool could be useful for creating paths. Site Designer also allows the use of feature lines for terrain modification instead of vertex-by-vertex modification. It allows importing and exporting LandXML files, which are used in Civil 3D.





2.2. Connecting to the existing terrain	Can connect surfaces that do not meet at edges. It is best to modify the contours rather than the 3D model for a smoother transition. In cases when contours cannot be modified sufficiently, the terrain has to be mod-ified vertex-by-vertex, which is ineffiecient. (4 pts) +1 Can use feature lines.
3.2. Routes	Cannot project as lines, but can make sub-surface or split for coloring. However, the selection method is slow. (3 pts) +1 Can use sidewalk tool.
3.3. Structures (amphi-theater + terrain modifica-tion)	Seating stairs as floors. Landform from contours. (4 pts) +1 Can use fea-ture lines.
6.1. File formats	Few export options. (2 pts) +1 LandXML. Few import options. (2 pts) +1 LandXML.

Total score improvement: 70+5 = 75 pts.

6.2. Self-reflection

6.2.1. Motivation

The thesis work began in April 2018. The author has prior experience teaching 3D modeling with Rhino at Aalto University, and has worked with several other 3D modeling software in offices and during studies. Making the design process as efficient as possible with the help of 3D modeling software has always been a personal goal for her. Designing landscape architecture has traditionally been considered a lengthy process, and students are expected to work long hours on their designs. The author considers it one of her goals to reduce the arduous workload. However, from her experience of working in an office, 3D models were not used in this manner. Instead of easing the workload, the 3D model was considered to add more work on top of the rest.

Disappointed in the inefficiencies of 3D modeling, the author has been searching for the most efficient method to 3D model landscape architecture designs. However, every new software she learned seemed to pose entirely new problems. Instead of finding one software that was above the rest, she found that every software seemed to have their own benefits and limitations. Which one to focus on, then? She had been part of the teaching team that decided to teach Rhino instead of SketchUp to new landscape architecture students. Had that been the right decision? Rhino had more features than SketchUp, but was it too difficult and inefficient to use for landscape architects? Was there another software that should be taught, instead?

6.2.2. Work process

Out of the author's desire to find the ideal software that new landscape architects should learn, was born the idea for the thesis. Ideally the author would have liked to learn several new software and include them in the practical software comparison - however, this was deemed to be too time-consuming within the thesis workload. Instead, she had to find some way to limit which software to include in the comparison. She started the thesis process by conducting small practical tests on 5 software that she already had experience with.

The author would have been happy to dedicate the entire thesis to practical testing - however, her arguments for choosing the thesis topic needed back-up. She could tell from her professional experience in 3D modeling and teaching 3D modeling what the situation was like - but this was not sufficient argumentation for a scientific paper. Based on her initial assumptions, she conducted a survey with Finnish landscape architects, hoping to find evidence for her argumentation.

The author, however, has some doubts on the validity of the results that can be found with a survey. Some of these concerns are listed in the survey methodology chapter. Another problem is that the amount of replies to the survey ended up being small - but the field of landscape architecture in Finland is small as well. It is hard to say how well these results can be generalised to the field in Finland overall - in a small population even slight differences can cause huge variations. The results of the survey give an idea of the situation in Finland, but should not be taken as absolute facts.

Another method that could have been considered is direct interviews with practitioners. However, in comparison the survey allows for a wider variety of opinions. Many opportunities for freeform replies were also included in the survey, making up for the lack of direct interviews. With the survey, the results are at least comparable, though the validity may be debatable. The numerical values produced in the survey allow analysis, which is not possible with interviews.

Prior to conducting the survey, a literature review was performed. After conducting the literature review, the author almost considered this to be sufficient back-up for her initial assumptions about the state of 3D modeling. However, the literature review could not say anything about the situation in Finland, which is what the assumptions were based on. The survey was conducted in part to relate the situation in Finland to the overall picture revealed in the literature review.

The literature review helped to reveal what is already known and what is not known - the knowledge gap. This helped to refine the research goals of the thesis into more concrete research questions in order to fill the knowledge gap. How well these research questions - and the research goals overall - have been answered, will be considered at the end of the self-reflection chapter.

After conducting the literature review and gathering the results from the survey, the main part of the thesis, the software comparison was started. The early practical testing had given no consideration to the methodology of the comparison and was mostly not used in the final software comparison. Now the choices made in the methodology had to be argued for. The practical testing was designed more carefully: the choice of software, design tasks and evaluation criteria were considered.

Originally the intention had been to include several new software into the software comparison, to ensure that there would be variety in the types of software compared - and to find new, unknown solutions. However, because the resulting workload would have been out of the scope of the thesis, in the end the software choices were made primarily based on the results of the survey as well as the professional 3D modeling experience of the author. The chosen software were all widely used by landscape architects in the survey - although some slightly more popular ones were passed over in favour of ones that the author had more recent experience with. Thus the software choices represent 3D modeling tools currently in use by Finnish landscape architects rather than new options. But in the end the intention of representing different types of software was achieved - the software were found to have fundamental differences in the ways they can be used most efficiently.

The two design tasks used in the comparison were chosen out of three possible design tasks that were previously completed by the author using Civil 3D. Having already done the design tasks allowed to list the steps that were taken to do the design tasks - and compare the steps taken to the evaluation criteria formed by the author. It was considered that creating a new design would not be beneficial for the purposes of the software comparison - a design made with the goal of filling all the criteria of a software comparison would not be a sound landscape architecture design. The idea of comparing the resulting designs made with different software was excluded as well - it would be difficult to tell which changes were due to the software and which were due to the author.

The software evaluation was conducted by testing the performance of each of the five software in the selected design tasks. The results were then compared to each other and represented in relative terms. Creating an absolute evaluation would be difficult, as software development could bring about unexpected improvements. Evaluations were based on to what extent the task could be completed as well as the efficiency of completing the task.

6.2.3. Fulfillment of research goals

The overarching goal of this thesis is to provide Finnish landscape architects with information on how they could do 3D modeling better. A literature review was performed to outline the knowledge gap, and a survey was performed to reveal the attitudes of Finnish landscape architects towards 3D modeling. The literature review revealed information that was gathered in similar surveys in USA and Latvia. These surveys give a framework against which the situation in Finland can be compared. In the literature review it was outlined that the statistics of 3D modeling by Finnish landscape architects was unknown. To reveal how 3D models are used by Finnish landscape architects, these research questions were defined:

- Who does landscape architecture 3D modeling in Finland and who doesn't? Why?
- How much are 3D models used as part of the design process?
- In what ways are 3D models used?
- What kinds of projects are 3D models used for?
- Which software are used in 3D modeling?
- Which benefits are desired from 3D models?
- Which benefits are gained from 3D models?
- What prevents Finnish landscape architects from taking full advantage of 3D modeling?

Prior to conducting the survey, it was determined that it could not give fully valid results on the following questions. However, the opinions of Finnish landscape architects could be gathered.

- Does 3D modeling increase the time spent in the design process?
- How does 3D modeling affect design costs?
- How does 3D modeling affect the design process in terms of creativity?
- How does 3D modeling affect the design results?

In the end it was determined that the questions about creativity and design results might be too difficult for respondents to answer directly. Instead, some underlying attitudes could possibly be gathered from other replies. It was considered that for these research questions other methods would give more conclusive results, but that would be out of the scope of this study. Instead, they could be research questions for further studies.

The survey was able to produce results on the statistics of 3D modeling in Finland, but this is limited by the sample size. The main research question for the survey was about the beliefs of benefits and limitations of 3D modeling. According to the survey results, the benefits of 3D modeling are appreciated by Finnish landscape architects but are not fully taken advantage of due to the perception that the benefit may not justify the cost in time and money.

Due to this, the efficiency of five 3D modeling software used in Finland was evaluated using two design tasks, split into steps used to complete the tasks. The goal was to find out if any software could be determined to be more efficient than others overall, or in specific tasks, and could be recommended to landscape architects over the others. It was found that performance was task-specific and the emphasis put on these tasks should be considered when choosing a suitable software. A secondary goal was that by revealing the inefficiencies, software developers could consider ways to improve them in the future. Some areas of improvement are pointed out in the software comparison.

Lastly, ways to improve the deficiencies, as revealed by the methods used in the study, were considered in the Conclusions chapter. The roles of different parties involved in landscape architecture 3D modeling were considered. It can be concluded that the improvement of the core software is the largest deciding factor, but landscape architects can affect how well they learn to use the tools that are available. Aalto University also plays a large role in forming the attitudes and skills towards 3D modeling during landscape architecture studies - whatever software was at some point taught in Aalto was found to be widely used by landscape architects. Therefore it is important for the university to consider if the most efficient 3D modeling tools are being taught, and update the curriculum as software development progresses.

6.3. Outlook

The field of digitalisation is rapidly developing, and often grandiose predictions are made of future technology. However, looking at the past predictions for today, they have not all come true. For example, we are not yet driving flying cars. And yet some developments have happened that no one could have predicted. This is why it is important to stay grounded in the possibilities of today. All the world's tomorrows are build on all the world's todays. Without understanding the situation of today, how could we understand and plan for tomorrow?

Instead of waiting for a future technological solution to fix all our problems, we must find solutions to our problems today. A new plug-in, a new software version or a new software may well be a future solution. But the future is not here yet, and cannot be counted on. The future is uncertain, and development does not occur automatically. Someone has to make it happen. The roles involved in landscape architecture 3D modeling development are discussed in the previous chapters. It is all of us that are building the future of landscape architecture.

Before thinking about the solutions of the future, we need to think about the solutions to the problems we are facing now. In order to think about solutions, first the problems have to be identified. That is the role of this thesis - to give an overview of current problems, as well as possibilities. How could we look into the future without understanding the situation of today?

According to James Sipes (2014) in "Integrating BIM Technology into Landscape Architecture" some landscape architects have the opinion that landscape architecture is too small a field to influence the development of a new software, so short-term solutions should be looked at instead. Lewis Richard Gill (2013) already tested a 3D modeling software dedicated to landscape architecture in his doctoral dissertation "A 3D landscape information model. Using real-time 3D graphics for site-based landscape design. ", but the development of such a software is still far from becoming reality. Instead it is suggested that tweaking the existing software is a short-term solution. (Sipes, 2014) The next chapter looks at ways software development could evolve in the long-term.

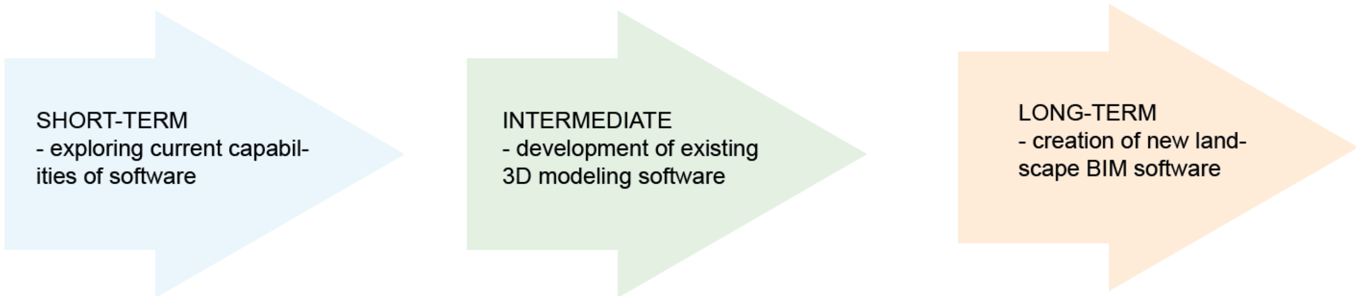


Figure 11. Future development of 3D modeling software.

6.3.1. Software development and design process

In this chapter the possible development directions of landscape architecture 3D modeling software are considered. The following chart depicts the role of 3D models in the landscape architecture design process currently.

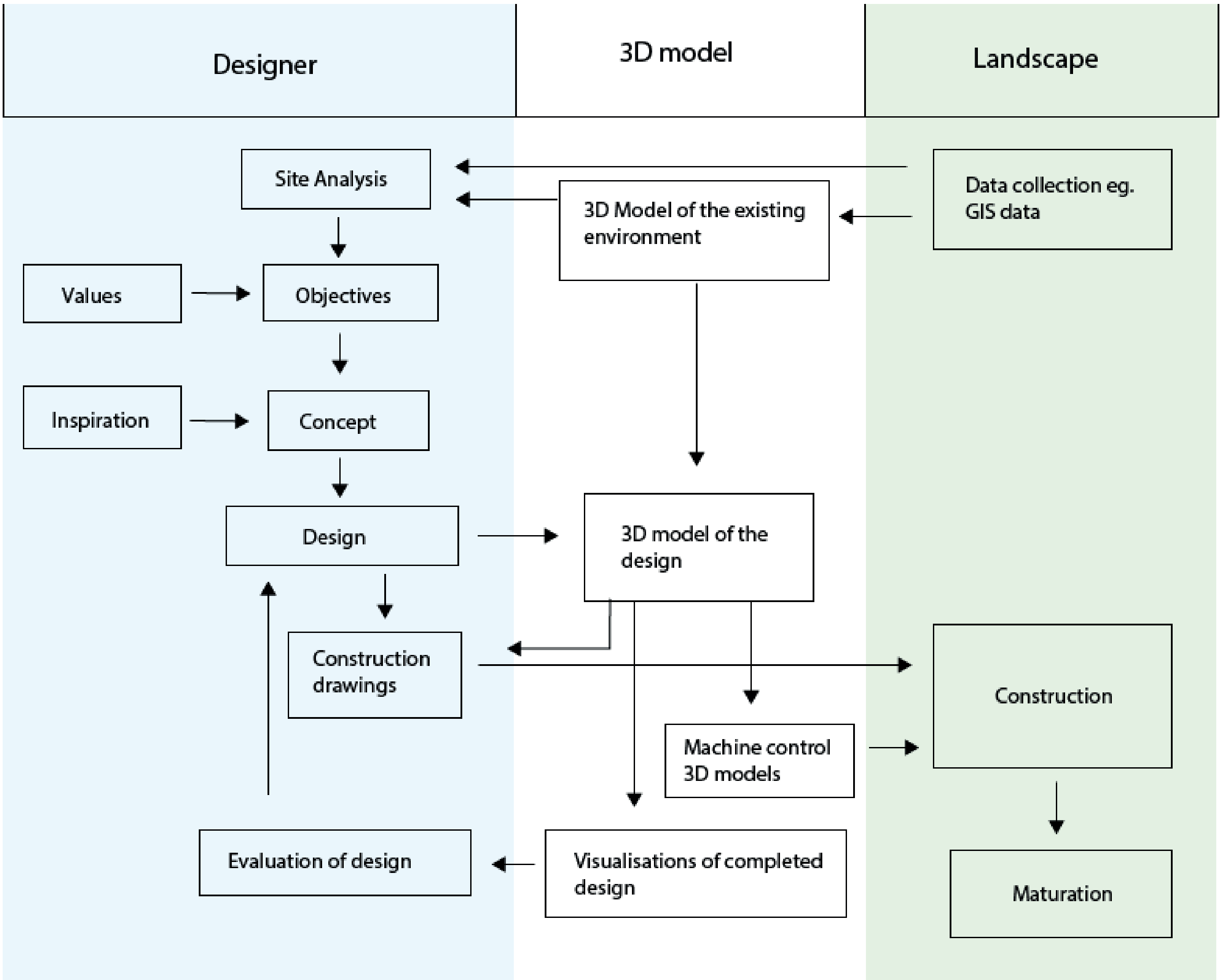


Figure 12. 3D modeling in the design process currently.

A 3D model of the existing environment can be constructed from laser scans, which helps with the site analysis. As the first design drafts are made, the design can then be transferred into the 3D model, which can be used to visualise the resulting design. Using the visualisations, it is possible for the designers as well as the clients to evaluate the design, and adjust the design as needed. Machine control models can also be produced from the finished 3D model to aid in the shaping of the landscape.

However, some problem points in this process can be identified. Having the construction drawings as a separate step for the designer to do means that every time the 3D model is, all the drawings must be updated by hand. Currently no software is capable of producing construction drawings from landscape information models. Most 3D modeling software that is used, for example, Sketchup and Rhino, can at best produce plans and sections. BIM software like Revit and ArchiCAD may be able to produce construction drawings from an architecture model, but they lack in the landscape architecture department.

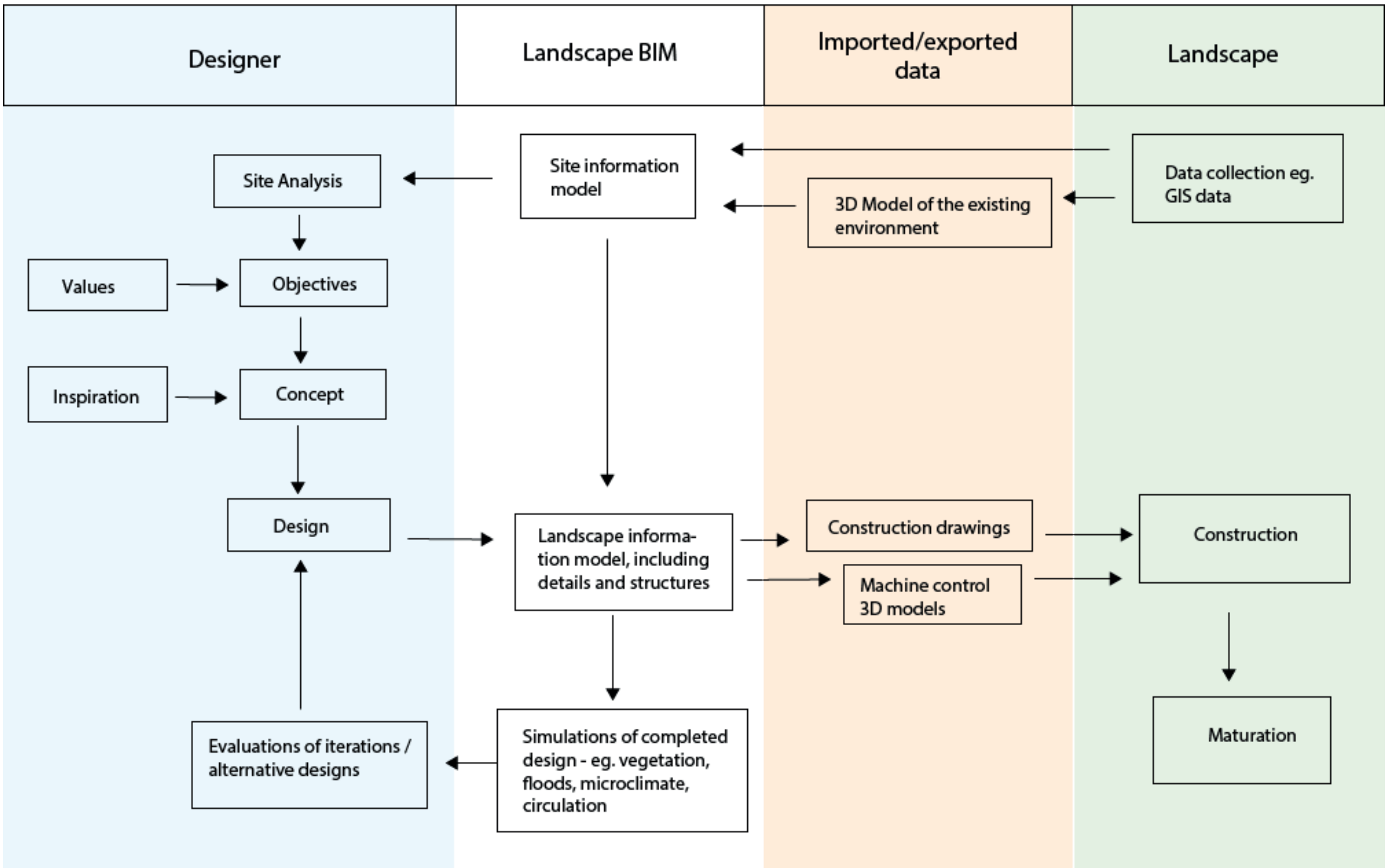


Figure 13. A possible future of landscape BIM.

Above is shown how the design process might change in the future with a fully developed landscape BIM software.

Ideally the software would be able to integrate all the GIS data, not just the laser scan, into the starting model. Then the tools of this software could be used to help in the analysis phase. The software would include construction information and vegetation information, so that any time the model is updated, the final construction and vegetation drawings would be updated as well. It would be useful as well if the design could be evaluated beyond visualisations - having simulations of the resulting microclimate, vegetation growth, flooding situation, etc. Then the design could be more easily evaluated from more than just an aesthetic viewpoint with hard data. Ideally the software would also save different versions of the design, so that these could be evaluated against each other.

In the doctoral dissertation “A 3D landscape information model. Using real-time 3D graphics for site-based landscape design” it was mentioned that an ideal software would allow you to just input your design objectives, and then the software would produce various designs that you could choose from (Gill, 2013). This could well be the final step of a LIM software one day.

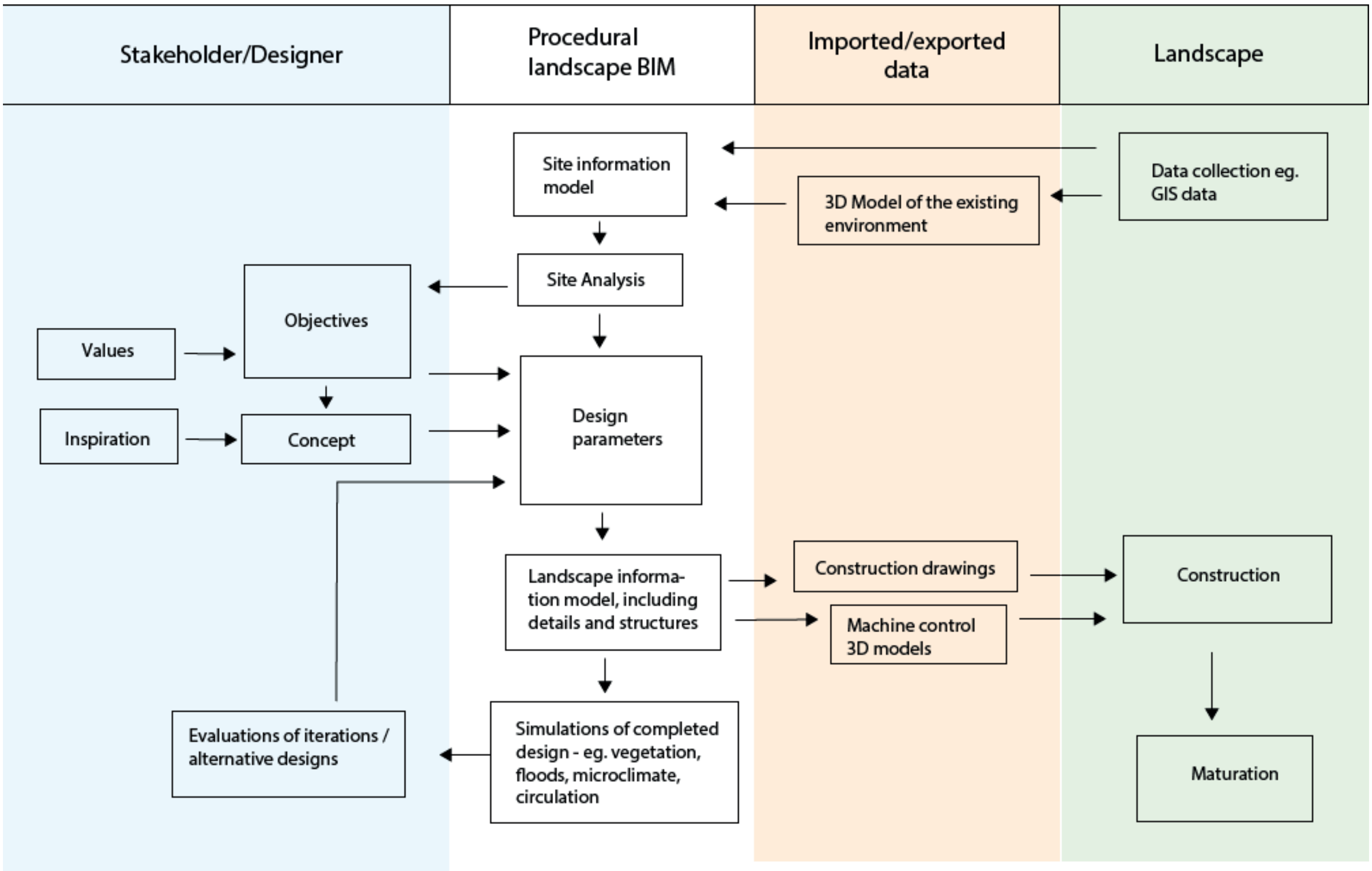


Figure 14. Further development of landscape BIM.

Above is shown how the design process might change further with a parametric landscape BIM software.

It should be noted that this reduces the role of the designer considerably: So much so that even the client himself could input the desired parameters and then simply pick the design he likes best. Some might think that this is the abolishment of the whole profession of landscape architecture, but we are still very far from the development of such a software. Even if such a software were developed, it would still require someone capable of operating the software. It is interesting to note, however, that such a software would allow more emphasis on the objectives, values and inspiration behind the design, because that is all the designer would be left to work with. As well the resulting design could be more easily evaluated against how well it fulfills those objectives with the help of simulations.

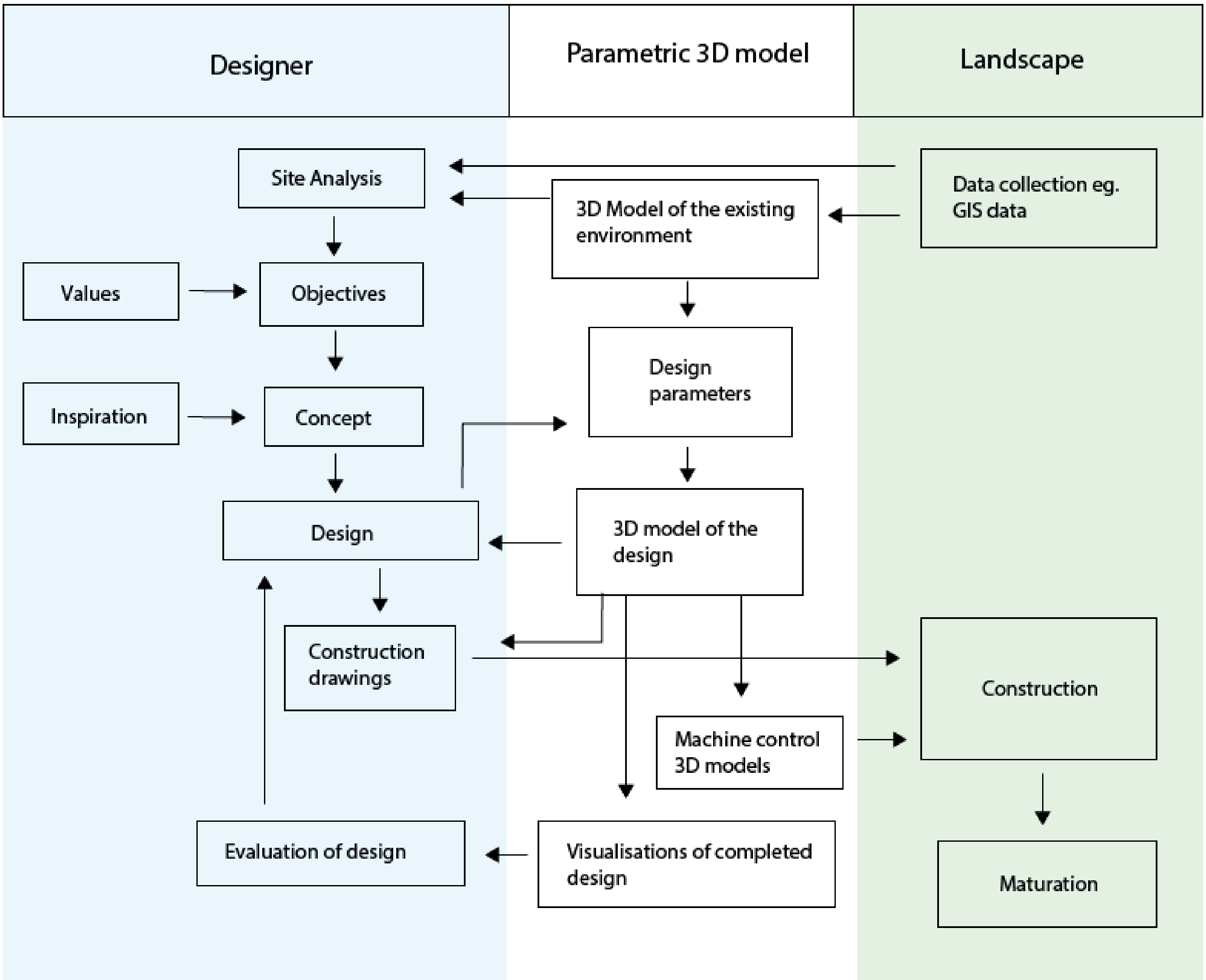


Figure 15. Parametric 3D modeling in landscape architecture currently.

Contrast the ideal situation with how parametric modeling is mainly used at this stage, as shown above. Currently parametric design may not always add value to the design process, which is related to the fact that to really make use of parameters, concrete data is needed. This data is largely, however, unavailable or inaccessible because of a lack of ways to integrate landscape data into the 3D model. When there is a lack of data, the only thing that can be parametrized are the design principles themselves, which, at this stage, do not really need parametrization. Therefore it would be preferrable to focus on data integration before focusing on parametric design. This is, of course, different in the field of architecture, where BIM tools and data integration already exist.

7. Appendix

7.1. Terminology

Wireframe modeling
Wireframe modeling is an abstract edge or skeletal representation of a real-world 3-D object using lines and curves.

Source: Techopedia.com. (no date). What is Wireframe Modeling? - Definition from Techopedia. https://www.techopedia.com/definition/10061/wireframe-modeling Accessed 3.9.2019

Surface modeling
Surface modeling is a mathematical technique for representing solid-appearing objects. Surface modeling is a more complex method for representing objects than wireframe modeling, but not as sophisticated as solid modeling. Although surface and solid models appear the same on screen, they are quite different. Surface models cannot be sliced open as can solid models. In addition, in surface modeling, the object can be geometrically incorrect; whereas, in solid modeling, it must be correct and seamless. This type of modeling is used for creating the external aesthetics of a product or design. It lacks the “watertight” feature of solid modeling because if you were to cut into the design, it would be hollow.

Source: Indovance.com. (2016). Solid Modeling Versus Surface Modeling. http://indovance.com/knowledge-center/info/solid-modeling-versus-surface-modeling/ Accessed 20.11.2018

Solid modeling
The object is considered a “watertight” model. A type of solid modeling technique is ‘surfacing’ (Freeform surface modeling). Here, surfaces are defined, trimmed and merged, and filled to make solid. The surfaces are usually defined with datum curves in space and a variety of complex commands.

Source: Indovance.com. (2016). Solid Modeling Versus Surface Modeling. http://indovance.com/knowledge-center/info/solid-modeling-versus-surface-modeling/ Accessed 20.11.2018
Wikipedia.org. (no date). Solid modeling. https://en.wikipedia.org/wiki/Solid_modeling Accessed 3.9.2019

Polygonal (or mesh) modeling
Polygons consist of geometry based on vertices, edges, and faces that you can use to create three-dimensional models. When you model with polygons you usually use three-sided polygons called triangles or four-sided polygons called quadrilaterals (quads). Some software, such as Maya also support the creation of polygons with more than four sides (n-gons) but they are not as commonly used for modeling.

A polygonal model represents points in 3D space connected by line segments to form a polygon mesh. Polygonal mesh files are planar, which means that they are represented by a series of flat facets. Therefore, curves can only be approximated through surface subdivision with a defined resolution.

Source: Knowledge.autodesk.com. (no date). Polygonal modeling. https://knowledge.autodesk.com/support/maya/learn-explore/caas/CloudHelp/cloudhelp/2016/ENU/Maya/files/GUID-7941F97A-36E8-47FE-95D1-71412A3B3017-htm.html Accessed 3.9.2019
Sculpteo.com. (no date). What is 3D modeling? https://www.sculpteo.com/en/glossary/3d-modeling-definition/ Accessed 3.9.2019

Curve (or patch) modeling
A type of modeling that relies on curves to generate surface geometry. The curves are driven by mathematical equations that are influenced by the designer using weighted control points.

A spline is a curve in 3D space defined by at least two control points. The most common splines used in 3D art are bezier curves and NURBS. A cage of splines is created to form a “skeleton” of the object you want to create. The software can then create a patch of polygons to extend between two splines, forming a 3D skin around the shape.

Spline modeling is used primarily for the creation of hard objects, like cars, buildings, and furniture. Splines are extremely useful when creating these objects, which may be a combination of angular and curved shapes.

Patch modelers use a network of control points to define and modify the shape of the patch, which is usually a lattice of either splines or polygons. These control points, called control vertices (CVs), exert a magnet-like influence on the flexible surface of the patch, stretching and tugging it in one direction or another. In addition, patches can be subdivided to allow for more detail and can be “stitched” together to form large, complex surfaces. Like spline modelers, patch modelers are very suitable for building organic forms.

Source: Sculpteo.com. (no date). What is 3D modeling? https://www.sculpteo.com/en/glossary/3d-modeling-definition/ Accessed 3.9.2019
Animationarena.com. (no date). Introduction to 3D modeling. http://www.animationarena.com/introduction-to-3d-modeling.html Accessed 3.9.2019
Ciambruno, Mark. (2003). 3D Modeling Basics. http://www.peachpit.com/articles/article.aspx?p=30594 Accessed 3.9.2019

Digital sculpting
This is a relatively new type of 3D modeling where the user interacts with the digital model as you would modeling clay. Users can push, pull, pinch, or twist virtual clay to generate their model.

Source: Sculpteo.com. (no date). What is 3D modeling? https://www.sculpteo.com/en/glossary/3d-modeling-definition/ Accessed 3.9.2019

Parametric modeling
Parametric modeling features objects that retain their base geometry information, such as their default shape, their current size, and how many segments their forms comprise. Because this information can still be accessed and changed even after the objects are modified, it allows the user to change or undo alterations to the object later on, and even increase or decrease its resolution. Although parametric modeling is usually spline-based, not all spline modelers are parametric.

Deformations applied to parametric objects can often be adjusted at any time, even though they may have been applied several operations ago. Contrast this to polygonal modeling, where after an object is created, its resolution is fixed (unless you tessellate or optimize it). Likewise, deforming a polygonal object permanently modifies it, so if you bend an object, then later want to reduce that bend significantly, you probably have to start over again with an unbent object.

Source: Ciambruno, Mark. (2003). 3D Modeling Basics. http://www.peachpit.com/articles/article.aspx?p=30594 Accessed 3.9.2019

Procedural modeling
Procedural modeling is an umbrella term for a number of techniques in computer graphics to create 3D models and textures from sets of rules.

Although all modeling techniques on a computer require algorithms to manage and store data at some point, procedural modeling focuses on creating a model from a rule set, rather than editing the model via user input. Procedural modeling is often applied when it would be too cumbersome to create a 3D model using generic 3D modelers, or when more specialized tools are required. This is often the case for plants, architecture or landscapes.

Sorce: Wikipedia.org. (no date). Procedural modeling. https://en.wikipedia.org/wiki/Procedural_modeling Accessed 3.9.2019.

7.2. Software manuals

Software	Company	Website	User manual
Sketchup 2019	Trimble	https://www.sketchup.com/	https://help.sketchup.com/en/sketch-up/sketchup
Blender 2.80	Blender Founda-tion	https://www.blender.org/	https://docs.blender.org/manual/en/dev/index.html
Z-Brush 2019	Pixologic	http://pixologic.com/	http://docs.pixologic.com/
Mudbox 2019	Autodesk	https://www.autodesk.com/products/mudbox/overview	https://help.autodesk.com/view/MBX-PRO/2019/ENU/
Maya 2019	Autodesk	https://www.autodesk.com/products/maya/overview	https://help.autodesk.com/view/MAYAUL/2019/ENU/
3DS Max 2019	Autodesk	https://www.autodesk.fi/prod-ucts/3ds-max/overview	http://help.autodesk.com/view/3DS-MAX/2019/ENU/
MODO	Foundry	https://www.foundry.com/prod-ucts/modo	https://learn.foundry.com/modo/con-tent/help/pages/user_guide.html
Rhino 6	Robert McNeel & Associates	https://www.rhino3d.com/	https://www.rhino3d.com/tutorials
Infraworks	Autodesk	https://www.autodesk.com/products/infraworks/overview	https://help.autodesk.com/view/INFM-DR/ENU/
Civil 3D	Autodesk	https://www.autodesk.fi/prod-ucts/civil-3d/overview	http://help.autodesk.com/view/CIV3D/2019/ENU/
ArchiCAD 22	Graphisoft	https://www.graphisoft.com/archicad/	https://helpcenter.graphisoft.com/us-er-guide-chapter/76124/
Revit 2019	Autodesk	https://www.autodesk.fi/prod-ucts/revit/overview	http://help.autodesk.com/view/RVT/2019/ENU/
AutoCAD 2019	Autodesk	https://www.autodesk.fi/prod-ucts/autocad/overview	https://help.autodesk.com/view/ACD/2019/ENU/
Microstation CONNECT	Bentley	https://www.bentley.com/en/products/brands/microstation	https://docs.bentley.com/LiveContent/web/MicroStation%20Help-v14/en/GUID-288FAFD8-1107-4FCB-9843-8BECC9099A06.html

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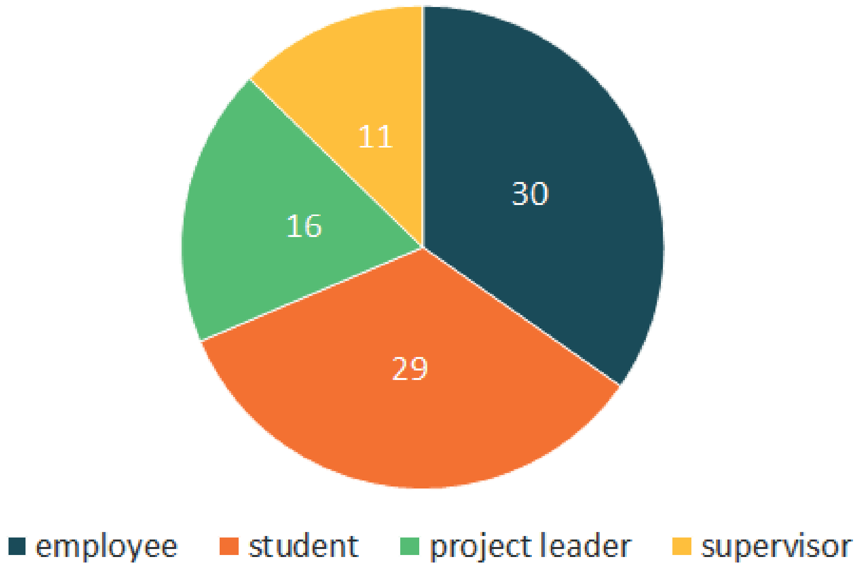
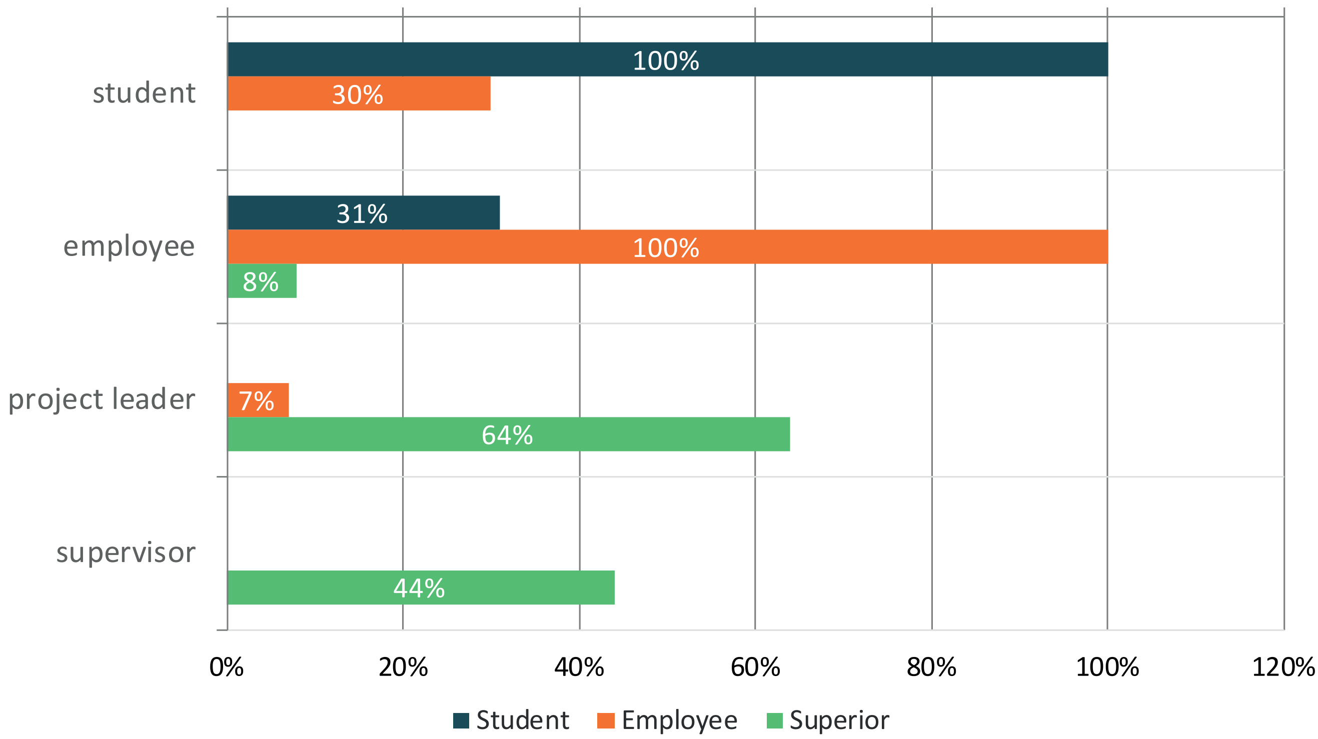
7.4. Full survey results

1. What is your work status in the field of landscape architecture?

Number of respondents: 73, selected answers: 86

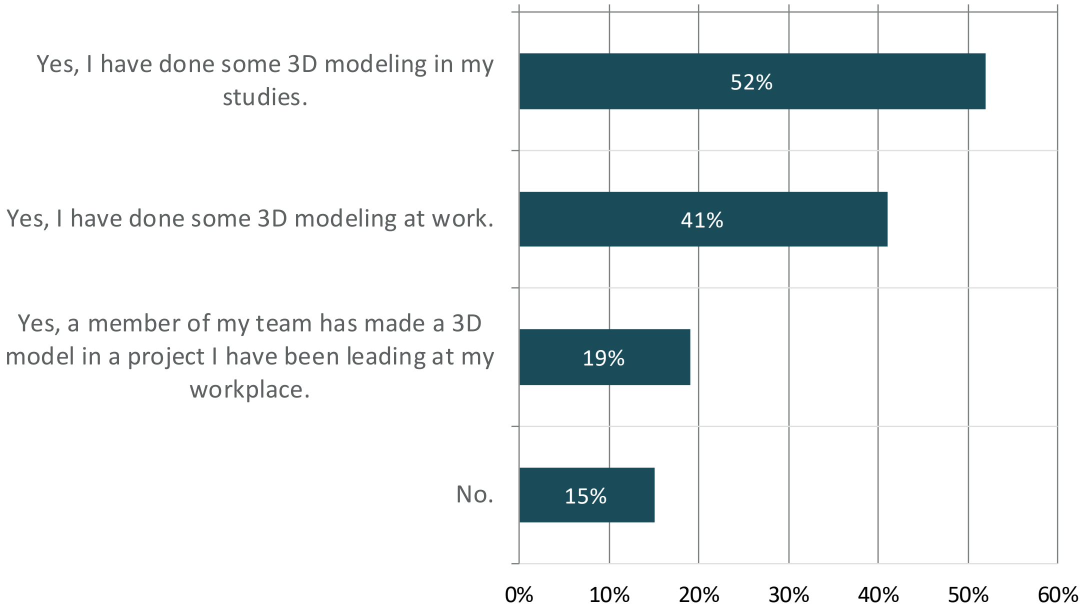


	n	Percent
student	29	39,73%
employee	30	41,1%
project leader	16	21,92%
supervisor	11	15,07%

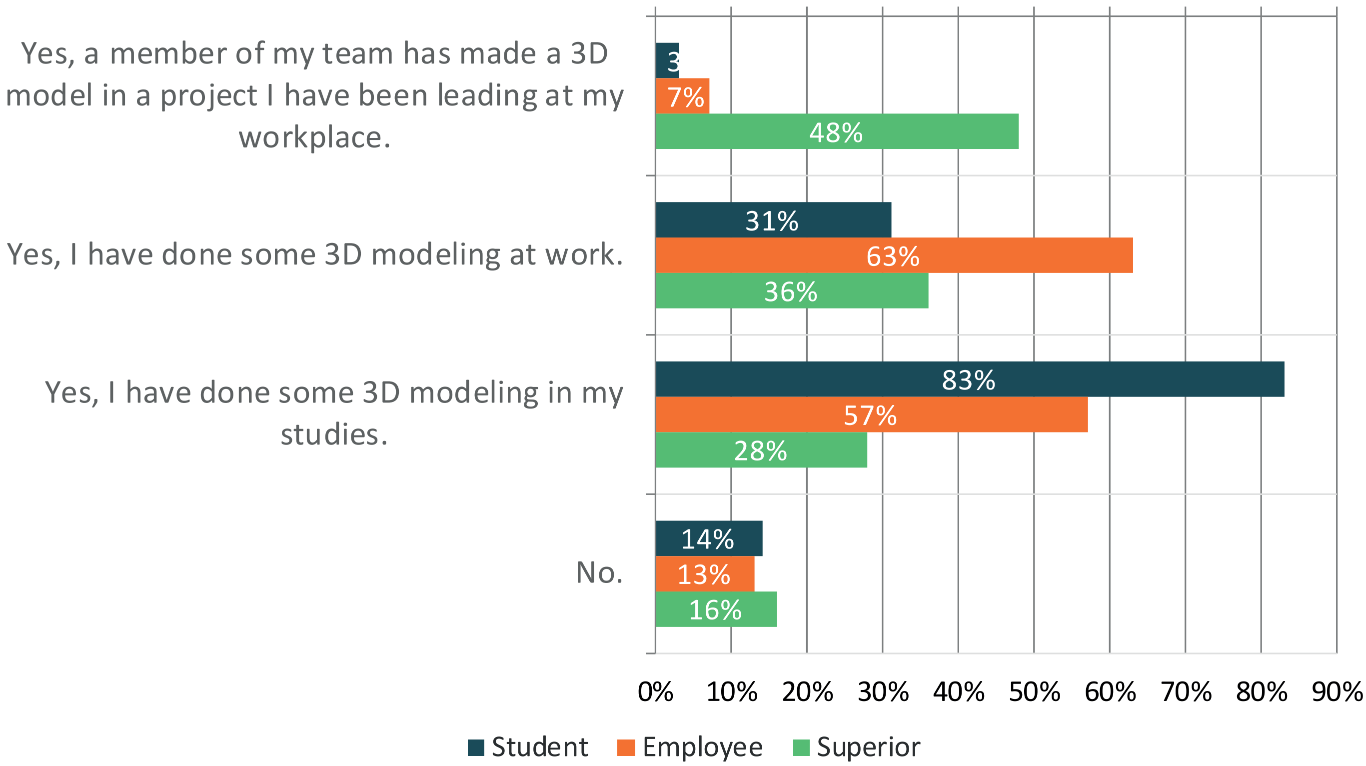


2. Have you ever made use of a 3D model in a landscape architecture project?

Number of respondents: 73, selected answers: 93

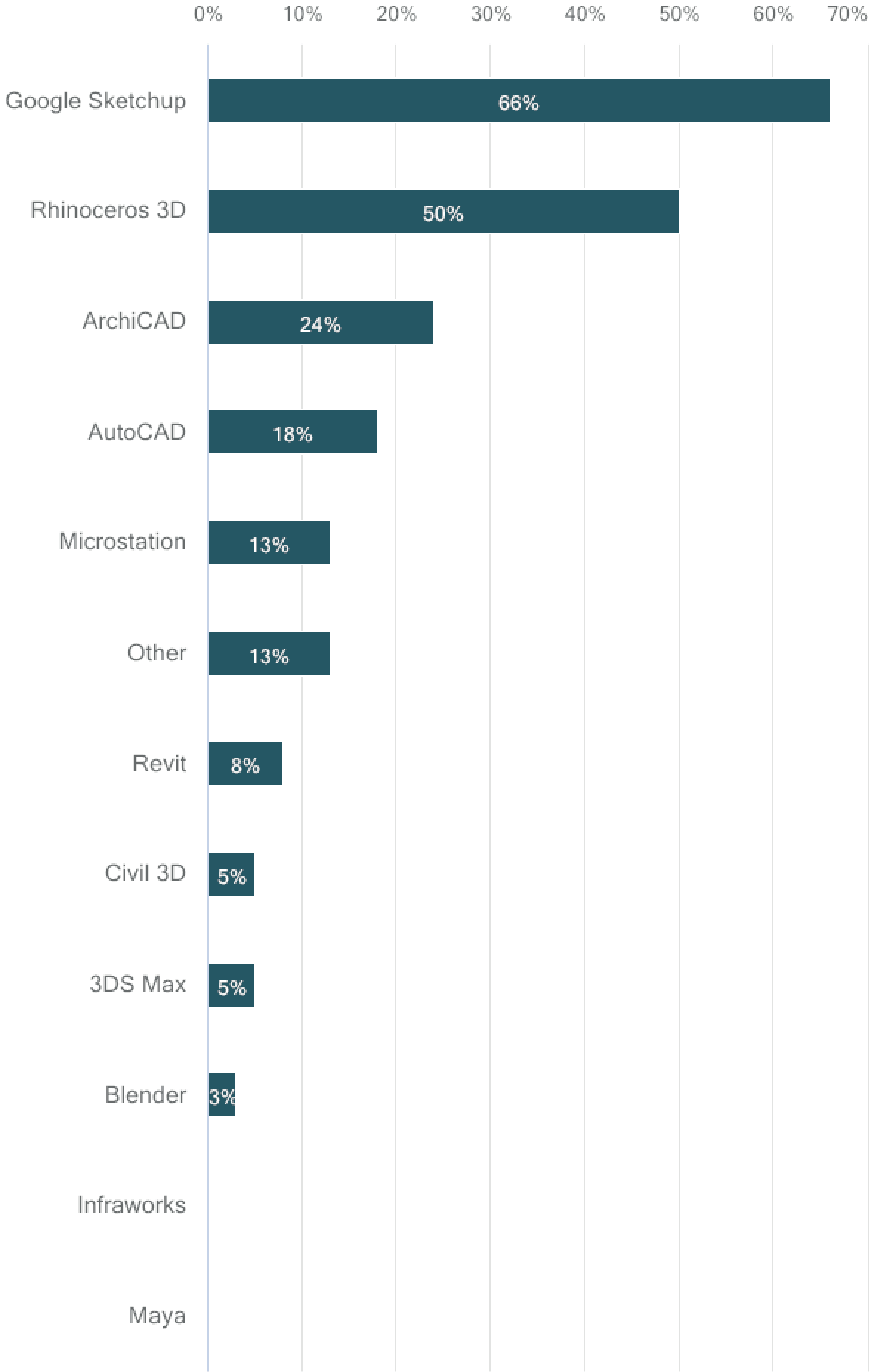


	n	Percent
Yes, a member of my team has made a 3D model in a project I have been leading at my workplace.	14	19,18%
Yes, I have done some 3D modeling at work.	30	41,1%
Yes, I have done some 3D modeling in my studies.	38	52,05%
No.	11	15,07%



3. Which software have you personally used for 3D modeling in your studies?

Number of respondents: 38, selected answers: 78



	n	Percent
Google Sketchup	25	65,79%
Rhinoceros 3D	19	50%
ArchiCAD	9	23,68%
Revit	3	7,89%
Infraworks	0	0%
Civil 3D	2	5,26%
3DS Max	2	5,26%
Maya	0	0%
Blender	1	2,63%
AutoCAD	7	18,42%
Microstation	5	13,16%
Other	5	13,16%

Answers given into free text field

Option names	Text
Other	Lumion
Other	Cinema 4D
Other	VectorWorks
Other	(QGIS)
Other	Pelimoottori Unreal

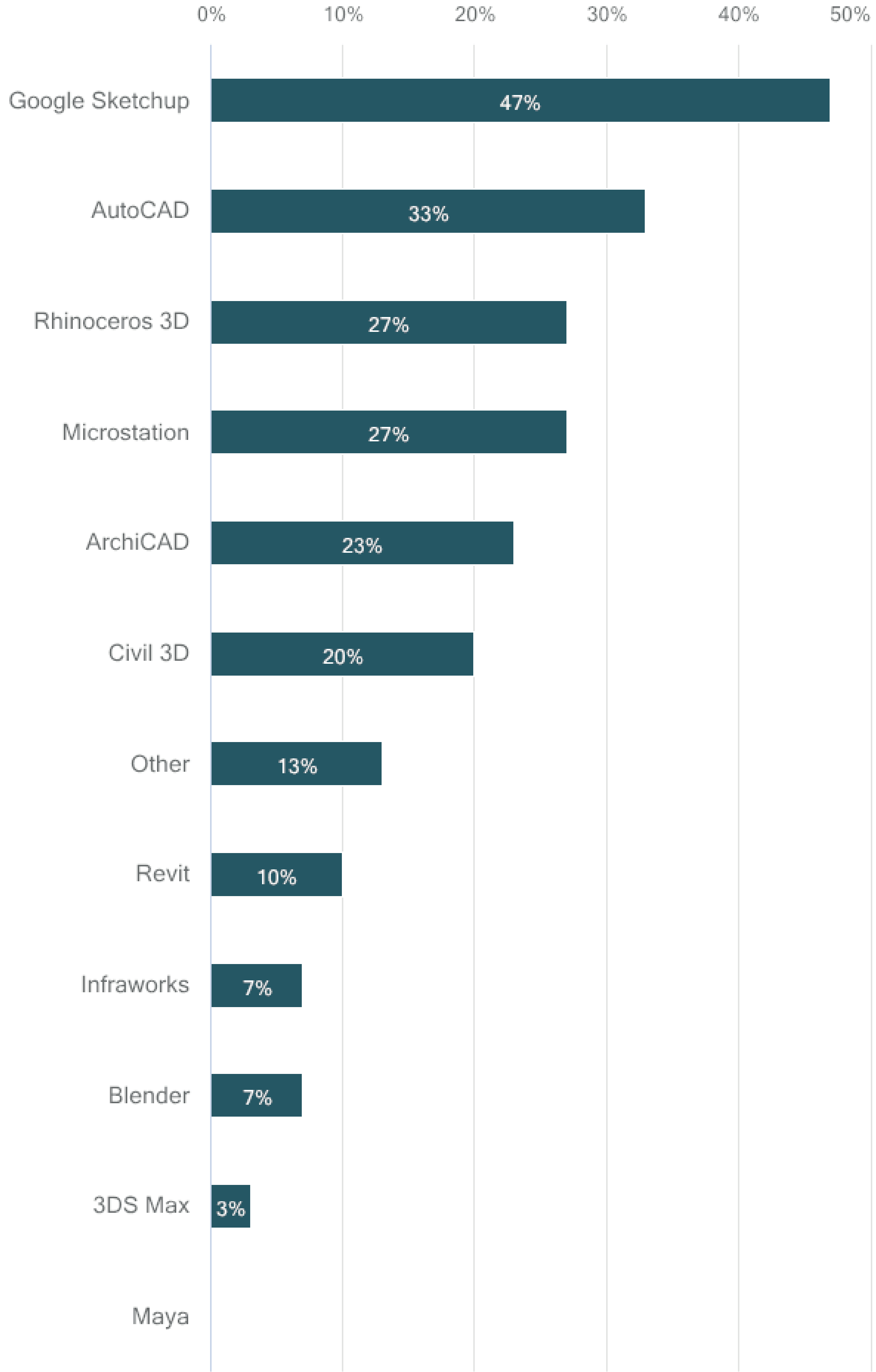
4. If you have used additional plug-ins with the software, you can write them down here.

Number of respondents: 6

Responses
grasshopper
Sketchupin kanssa Thea Renderiä
Grasshopper, Vray
Lands Design
Rhino+Grasshopper, Blender+BlenderGIS
Grasshopper

5. Which software have you personally used for 3D modeling at work?

Number of respondents: 30, selected answers: 65



	n	Percent
Google Sketchup	14	46,67%
Rhinoceros 3D	8	26,67%
ArchiCAD	7	23,33%
Revit	3	10%
Infraworks	2	6,67%
Civil 3D	6	20%
3DS Max	1	3,33%
Maya	0	0%
Blender	2	6,67%
AutoCAD	10	33,33%
Microstation	8	26,67%
Other	4	13,33%

Answers given into free text field

Option names	Text
Other	Lumion
Other	Cinema 4D
Other	VectorWorks
Other	Novapoint 20.0

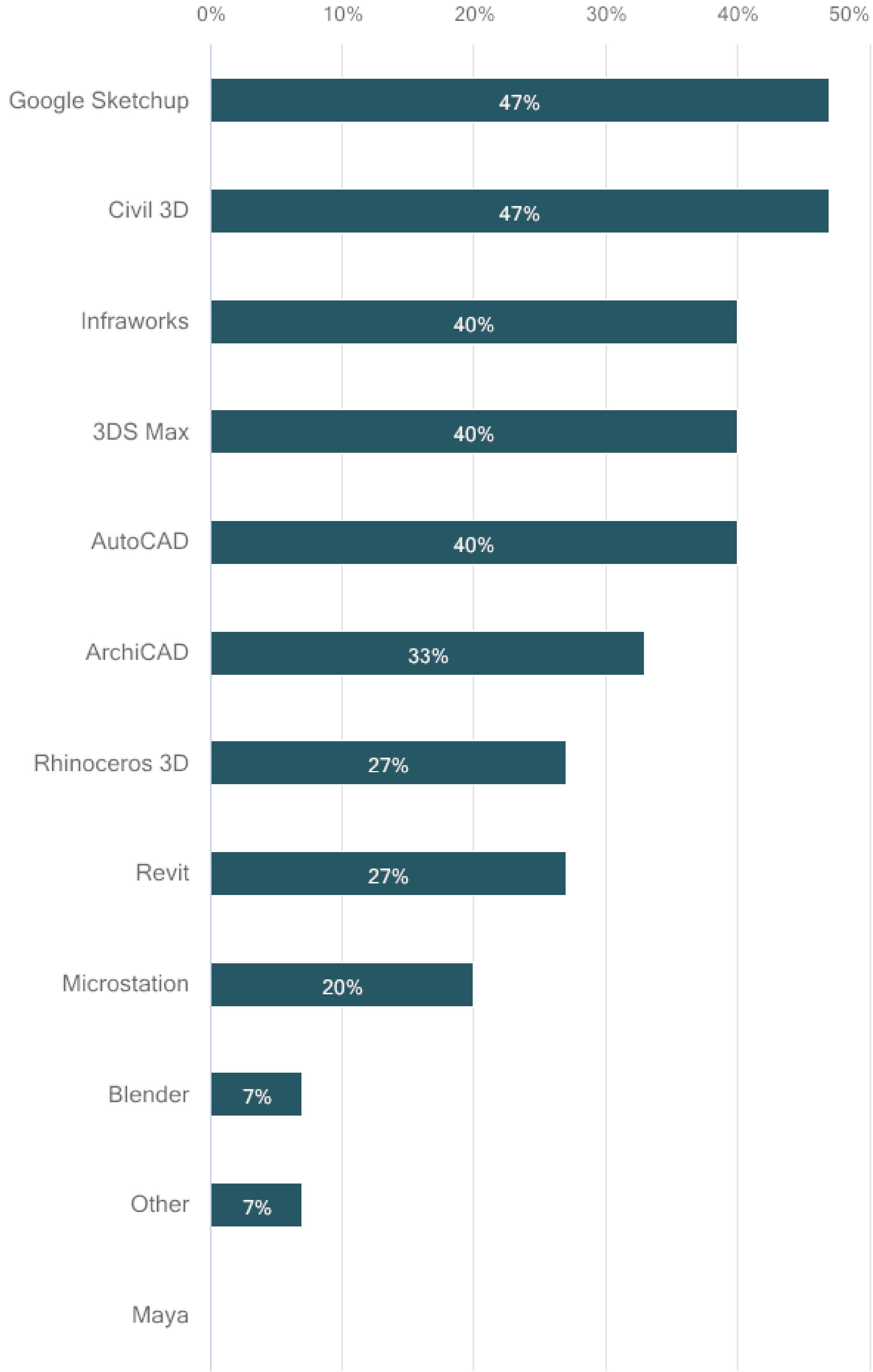
6. If you have used additional plug-ins with the software, you can write them down here.

Number of respondents: 7

Responses
TerraModeler
Terrasolid ohjelmistoja
Grasshopper, Vray
Novapoint Landscape
Blender+BlenderGIS
En tiedä mikä on plug-in, mutta Microstationissa käytössäni on TerraModeler-mallinnusohjelma.
Terra Modeller

7. Which software has your team used for 3D modeling in your workplace?

Number of respondents: 15, selected answers: 50



	n	Percent
Google Sketchup	7	46,67%
Rhinoceros 3D	4	26,67%
ArchiCAD	5	33,33%
Revit	4	26,67%
Infraworks	6	40%
Civil 3D	7	46,67%
3DS Max	6	40%
Maya	0	0%
Blender	1	6,67%
AutoCAD	6	40%
Microstation	3	20%
Other	1	6,67%

Answers given into free text field

Option names	Text
Other	Tekla Civil

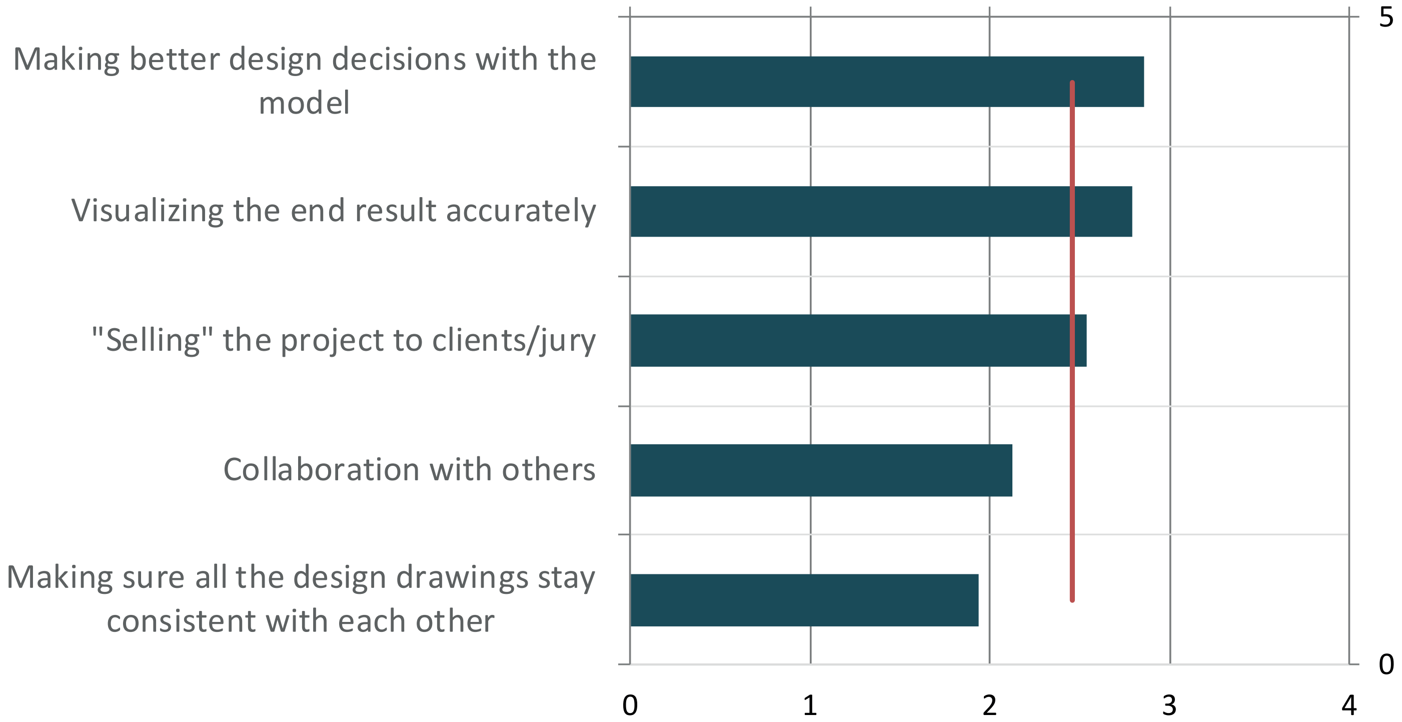
8. If you have used additional plug-ins with the software, you can write them down here.

Number of respondents: 1

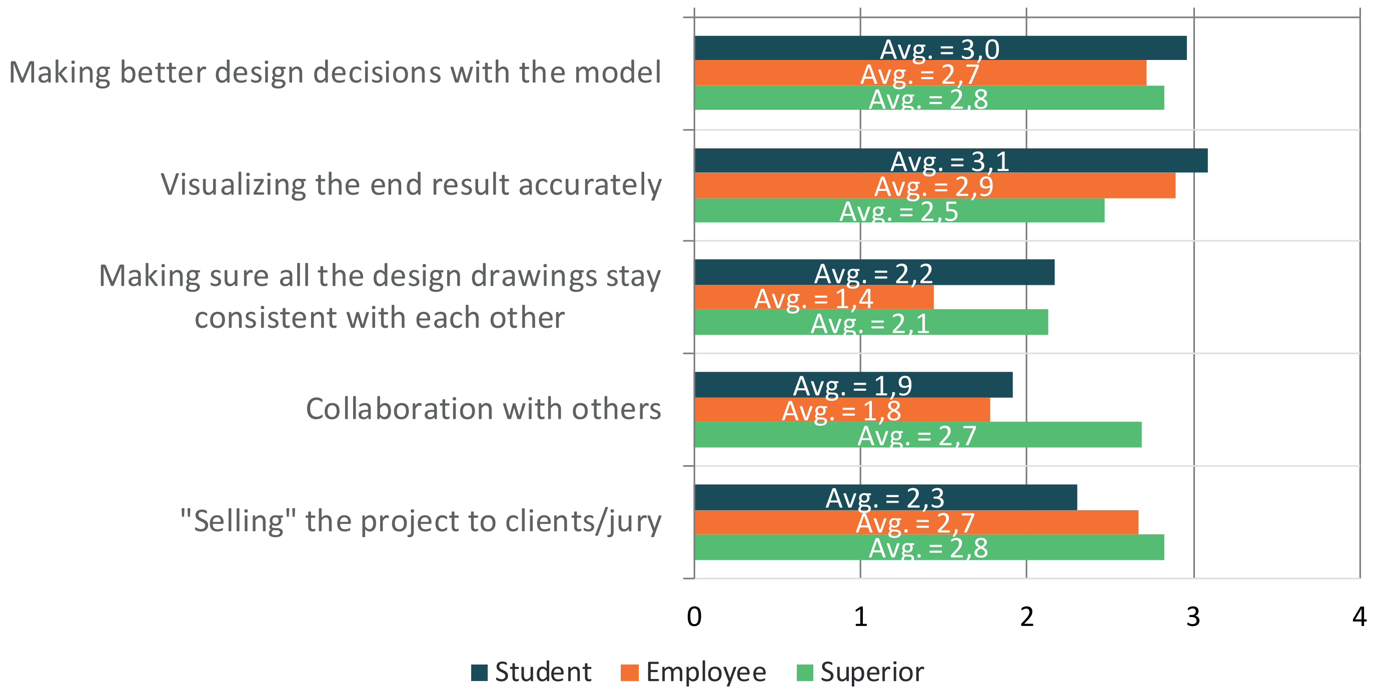
Responses
Grasshopper (Rhino)

9. How important have these reasons been for you in deciding to use a 3D model for your project?

Number of respondents: 49



	unim-portant	not very impor-tant	neither unimpor-tant / im-portant	impor-tant	very im-portant	To-tal	Av-er-age	Me-dian
Making better design de-cisions with the model	3	4	4	24	14	49	2,86	3
	6,12%	8,17%	8,16%	48,98%	28,57%			
Visualizing the end result accurately	2	5	9	18	15	49	2,8	3
	4,08%	10,2%	18,37%	36,74%	30,61%			
Making sure all the design drawings stay consist-ent with each other	10	8	13	9	8	48	1,94	2
	20,83%	16,67%	27,08%	18,75%	16,67%			
Collaboration with others	4	9	14	17	3	47	2,13	2
	8,51%	19,15%	29,79%	36,17%	6,38%			
“Selling” the project to clients/jury	5	4	11	16	12	48	2,54	3
	10,42%	8,33%	22,92%	33,33%	25%			
Total	24	30	51	84	52	241	2,46	3



10. If you have other reasons you have decided to use a 3D model, you can write them down here.

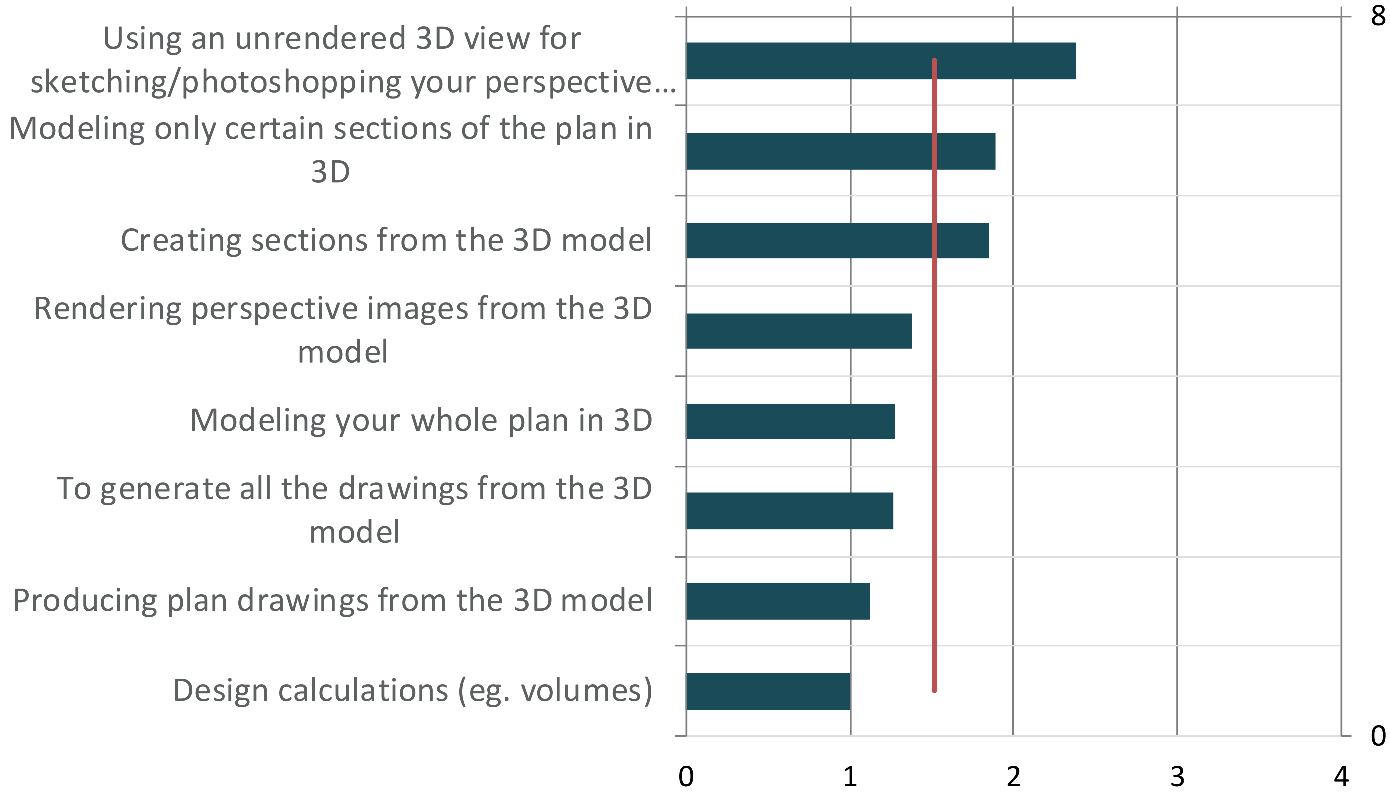
Number of respondents: 17

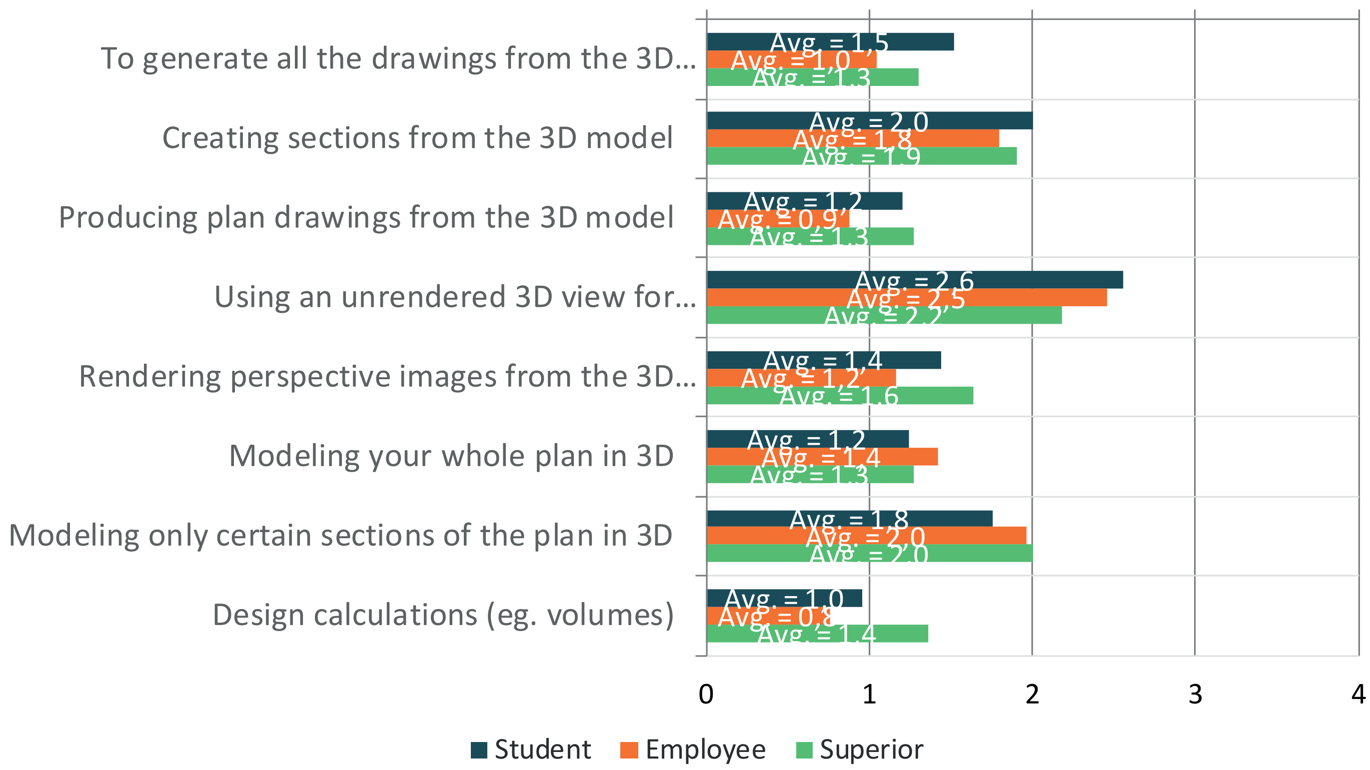
Responses
3D-mallin avulla voi varmistaa, että suunnitelmaan ei synny epäjatkuvuuskohtia tai eri osa-alueiden päällekkäisyyksiä, jotka paperilla toimivat mutta 3D:nä ja todellisuudessa eivät. Lisäksi tärkeä työkalu omassa suunnittelussa idean ja tilakokemuksen testaamiseen sekä paikkaan eläytymiseen.
Tilaajan vaatimus.
Tilaaja vaatii
3D-mallinnus on mielekkään tuntuista ja “tätä päivää” suunnittelijan näkökulmasta. Nuorille suunnittelijoilla alkaa olla jo jopa hankalaa hahmottaa erisuuntaisista 2D-kuvista kokonaisuutta.
Käytin 3D-mallia ensisijaisesti siihen, että sain maastomallin - joka oli suhteellisen pienikokoinen - tuotettua tarkkana mallina. Teetin mallin puusta CNC-jyrsimellä.
Yhdessä hankkeessa suunniteltiin ensin 2d -muodossa mutta tilaaja halusi, että tehdään lopuksi pintamalli.
Kaikkia asioita ei voi hahmottaa kunnolla 2D:nä ja ideoiden testaaminen 3D:nä paljastaa monesti asioita, joita ei yksinkertaisesti huomaa 2D:ssä.
3D malli osoittaa lähes aina jotain ongelmia jotka jää 2Dssä huomiotta. 3D ohjelmissa on periaatteessa nopeammat työkalut tasauksien ja luiskauksien tekoon ja testaamiseen. Näkee myös heti millaisesta massasiirroista tulee kyse suunnitelman kanssa.
Jos sitä on vaadittu. Yleensä ei ole mihinkään ylimääräiseen aikaa eli jos 3D:tä ei erikseen vaadita, en ole sitä tehnyt.

3D-mallintaminen on erityisen tärkeää rakenne- ja maisemasuunnittelun yhteensovittamisessa
Käsinpiirettyjen perspektiivikuvien referenssi-/pohjamateriaaliksi.
Helpompi kommunikoida muiden kanssa. Pystyy hahmottamaan helpommin ja ymmärtämään paremmin asioita.
Helposti menee sekaisin visualisointiin tähtäävä mallintaminen ja mallipohjainen suunnittelu, jossa taas yleensä tärkein anti on yhteensovitus muiden tekniikka-alojen kanssa. Mallipohjainen suunnittelu vaatii uuden työtavan omaksumista ja sitä että mallintamisesta oikeasti löytää hyötyjä suunnitteluun. Visualisointiin tähtäävä mallintaminen yleensä taas voidaan tehdä sittenkin, kun suunnitelmat ovat jo ns. valmiita ja tällöin on tärkeää hioa yksityiskohtia visuaalisuuden vuoksi kohdalleen. Tavoitteena tietysti olisi, että nämä asiat palvelisivat toisiaan ja että ei tehtäisi eri tarkoituksia varten ylimääräistä mekaanista työtä, mutta toistaiseksi ovat olleet vielä aika lailla erillään.. Myös keveät vaihtoehtotarkastelut suunnittelun alkuvaiheessa tehdään usein 3D-mallina, mutta tällöinkään tehtyä mallia ei yleensä jatkohyödynnetä (tai sitä ei ole mahdollista hyödyntää) jatkosuunnittelussa. Workflow suunnittelun alusta toteutussuunniitteluun ja visualisointiin on vielä täynnä aukkoja!
- Hankalien kohtien tarkistaminen, mallintamatta koko suunnitelmaa. - Suunnitteluratkaisuiden nopea kokeileminen (erityisesti opiskellessa)
Tietomalli oli tilaajan vaatimus eri alojen suunnitelmien yhteensovittamista varten
Lopputuloksen visualisoimisen helpottaminen, niin että 3D-malli toimii visualisointikuvan pohjana ennen photarointia.
massalaskenta, koneohjausmalli

11. How often have you used 3D modeling as a part of the design process in these ways?

Number of respondents: 52





	Never	Rarely	Some-times	Often	Always	To-tal	Aver-age	Medi-an
To generate all the drawings from the 3D model	19	10	8	12	0	49	1,27	1
	38,77%	20,41%	16,33%	24,49%	0%			
Creating sections from the 3D model	8	11	15	15	2	51	1,84	2
	15,69%	21,57%	29,41%	29,41%	3,92%			
Producing plan drawings from the 3D model	18	17	8	8	0	51	1,12	1
	35,29%	33,33%	15,69%	15,69%	0%			
Using an unrendered 3D view for sketching/ photoshopping your perspective drawings	4	4	15	23	4	50	2,38	3
	8%	8%	30%	46%	8%			
Rendering perspective images from the 3D model	17	10	12	9	2	50	1,38	1
	34%	20%	24%	18%	4%			
Modeling your whole plan in 3D	16	15	8	11	0	50	1,28	1
	32%	30%	16%	22%	0%			
Modeling only certain sections of the plan in 3D	7	12	15	16	2	52	1,88	2
	13,46%	23,08%	28,84%	30,77%	3,85%			
Design calculations (eg. volumes)	22	12	13	3	1	51	1	1
	43,14%	23,53%	25,49%	5,88%	1,96%			
Total	111	91	94	97	11	404	1,52	1,5

1

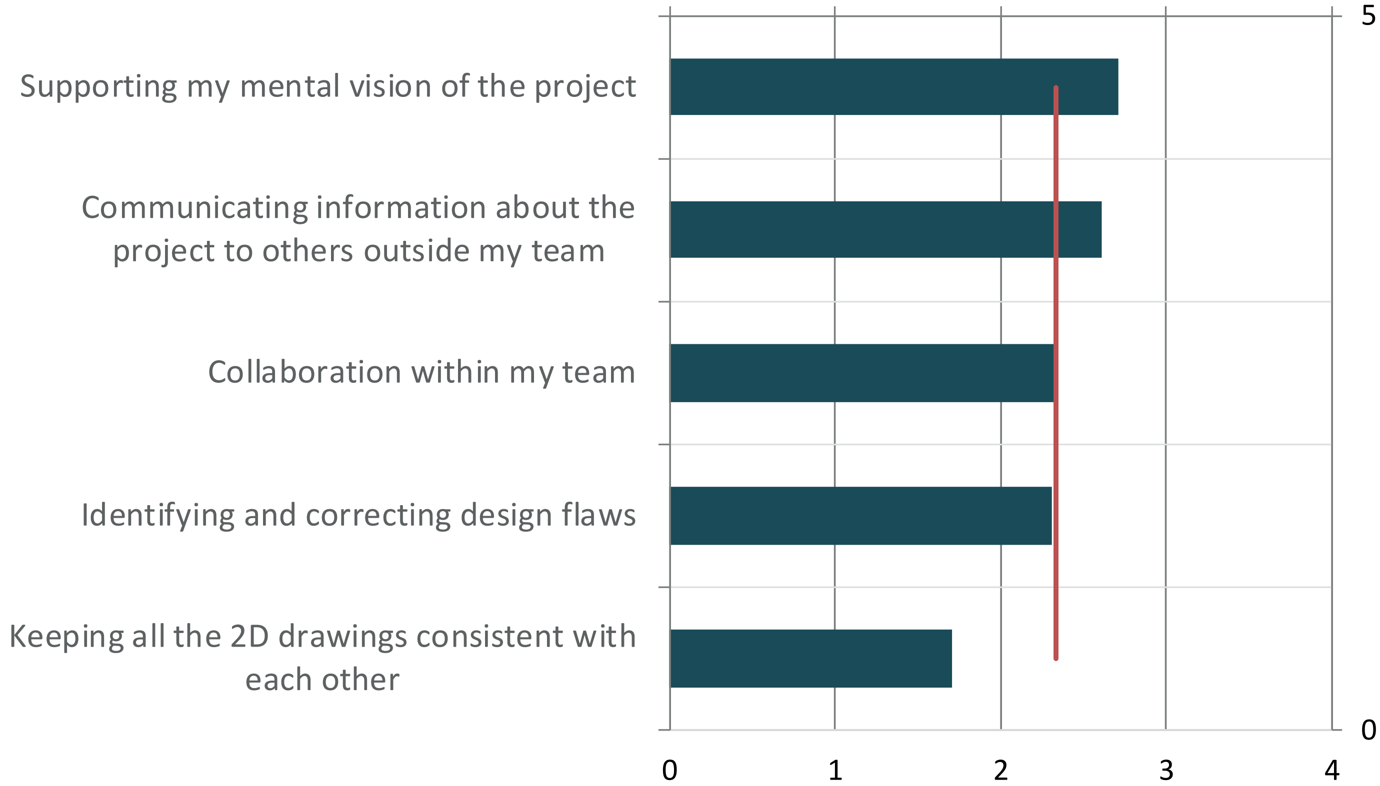
2. If you have used a 3D model in other ways, you can write them down here.

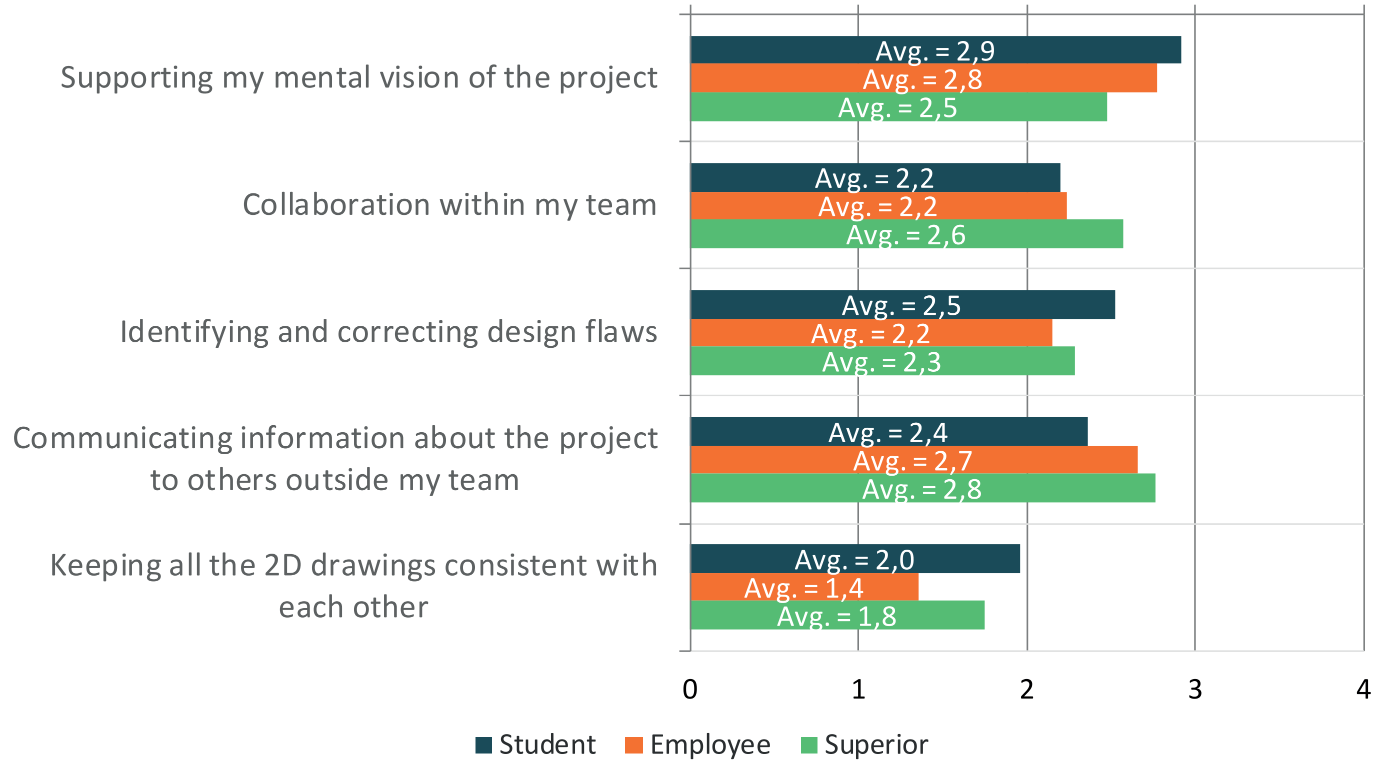
Number of respondents: 9

Responses
Pinnantasaussuunnittelu: korkeuskäyrien tuottaminen
Kokouksessa päätöksen työkalu.
Koko mallin teko liittyy yleensä tietomallien jakoon muiden yhteistyökumppanien kanssa.
Suunnitteluratkaisujen parempi hahmottaminen
Monialahankkeiden yhteensovitus, suunnitelman yhteensovitus olevien rakenteiden kanssa, tila- ja näkymätarkastelut, maastomallinnus työmaan koneohjausta varten.
interaktiivisena mallina
Olen tehnyt ns palikkamallin illustroinnin pohjaksi usein.

Pohjapiirroksilla on tällä hetkellä varsin kovat vaatimukset niiden ulkonäön suhteen. Vaatii tilaajilta myös höllennyksiä tiettyjen viivatyyppien ja rastereiden käytön suhteen, jotta voitaisiin tuottaa pohjapiirroksia suoraan malleista. On kuitenkin syynsä miksi pohjapiirroksilla on kovat vaatimukset, onko malleista vielä mahdollista saada ulos pohjakuvaa, johon saisi kaiken informaation tarpeeksi havainnollisesti esille? Ainakin vaatii työkalujen ja template-tiedostojen kovaa kehittämistä. Lisäksi työelämässä määrälaskennat ovat tärkeä osuus työtä, joten on erittäin tärkeä näkökulma että mallista saataisiin hyötyä määrälaskentoihin.
Väyläsuunnittelussa välttämätön nykyään.

13. How beneficial has a 3D model been for you in these parts of the design process? Number of respondents: 62





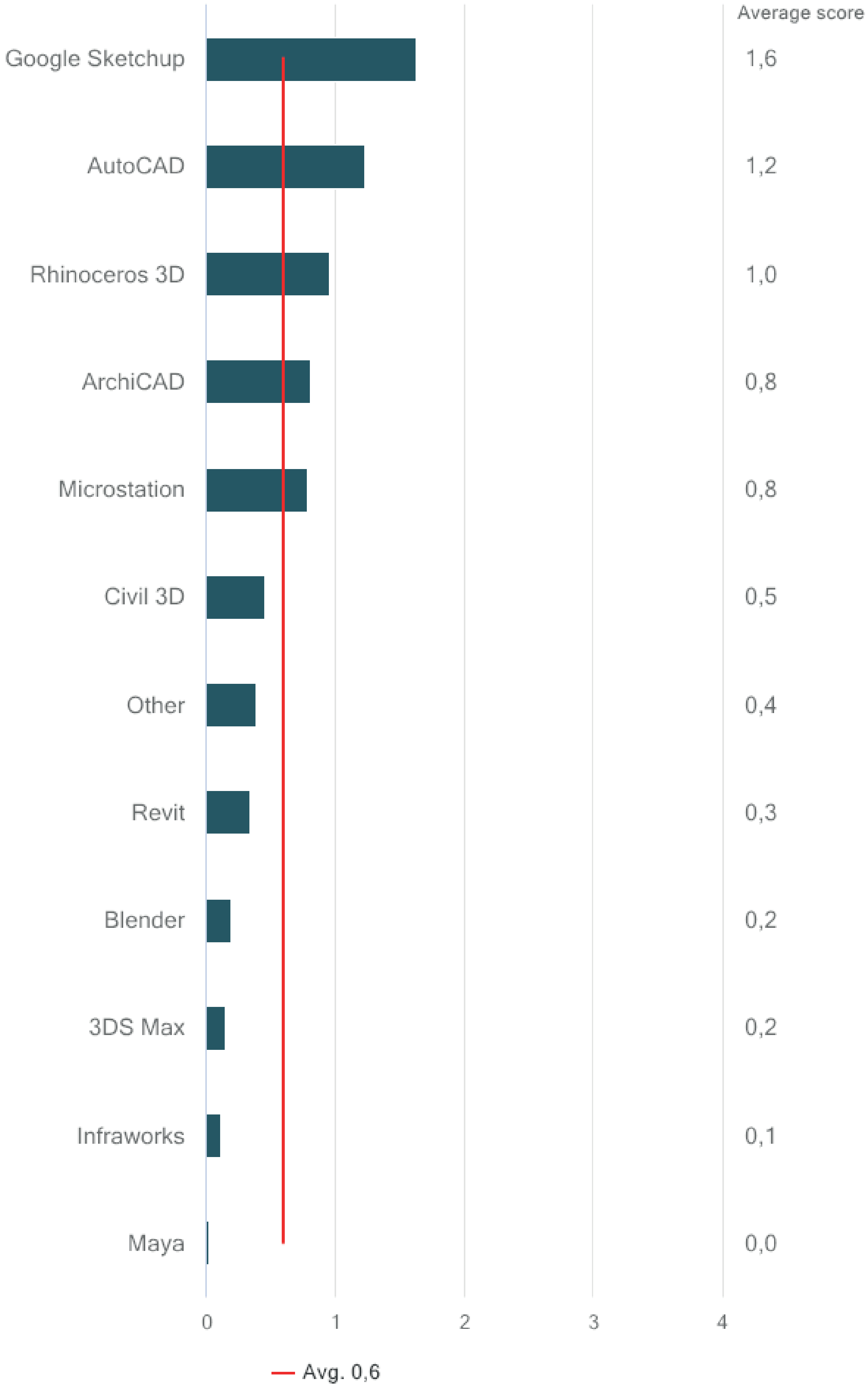
	unnecessary	not very beneficial	somewhat beneficial	beneficial	necessary	Total	Average	Median
Supporting my mental vision of the project	2	1	16	37	6	62	2,71	3
	3,22%	1,61%	25,81%	59,68%	9,68%			
Collaboration within my team	1	8	26	22	4	61	2,33	2
	1,64%	13,11%	42,62%	36,07%	6,56%			
Identifying and correcting design flaws	3	12	17	23	7	62	2,31	2
	4,84%	19,35%	27,42%	37,1%	11,29%			
Communicating information about the project to others outside my team	2	8	11	32	9	62	2,61	3
	3,23%	12,9%	17,74%	51,61%	14,52%			
Keeping all the 2D drawings consistent with each other	10	16	18	16	1	61	1,7	2
	16,39%	26,23%	29,51%	26,23%	1,64%			
Total	18	45	88	130	27	308	2,33	3

14. If you have gotten other benefits from a 3D model, you can write them down here. Number of respondents: 7

Responses
Korkeuskäyrien tekeminen erityisen kätevää
Myyntimateriaalia asiakkaalleeni
Massalaskenta
Maaperämalli helpotti puiston suunnittelua kun osattiin paremmin arvioida raitin rakennekerrosten törmäys kallioon tai savikerrokseen ja vältyttiin turhimmilta räjäytyksiltä. Sama hyöty oli 3D-johtokartan kanssa. Leikattu rgb-pistepilviaineisto auttoi hahmottamaan suunnittelukohteen ympäristön paremmin kun siitä saa photorealistisuutta lähentelevän vaikutelman paikan tilallisuudesta ja esim puiden korkeuksista. Tilaajan kanssa on helppo keskustella suunnitelmasta pyörittelemällä mallia ja leikkaamalla siitä useita haluttuja leikkauksia staattisten piirustusten sijasta tai lisäksi.
pitkälti (interaktiivisen) mallinnusosaamisen ansiosta olen saanut kolme työpaikkaa
3D-mallista ei sinänsä ole ollut mitenkään hyötyä 2D-piirustusten yhdenmukaisuuden varmistamisessa. Koska suunnitteluprosessia on tällä hetkellä lähes mahdoton saada kulkemaan 3D:nä alusta loppuun, on hyvinkin suuri riski että malleissa on ristiriitoja piirustuksiin nähden. Näin ei tietenkään saisi olla, mutta koska näin hyvin helposti tapahtuu, tärkeää on tiedostaa ja dokumentoida asia ylös tietomalliselostukseen tai vastaavaan. Ongelma on se että esimerkiksi jonkin linjauksen muutos 2D-kuvaan on nopea tehdä, mutta saman tekeminen malliin voi olla niin hidasta, että mallia ei ehditä päivittämään samaan tahtiin. Eli homma menee juurikin nurinkurisesti... oikeasti toimivassa mallipohjaisessa suunnittelussa 3D-mallista tuotettaisiin tiedot 2D-kuviin, eikä toisin päin.
massalaskenta, koneohjausmalli

15. How would you rate your familiarity with these software in 3D modeling?

Number of respondents: 52

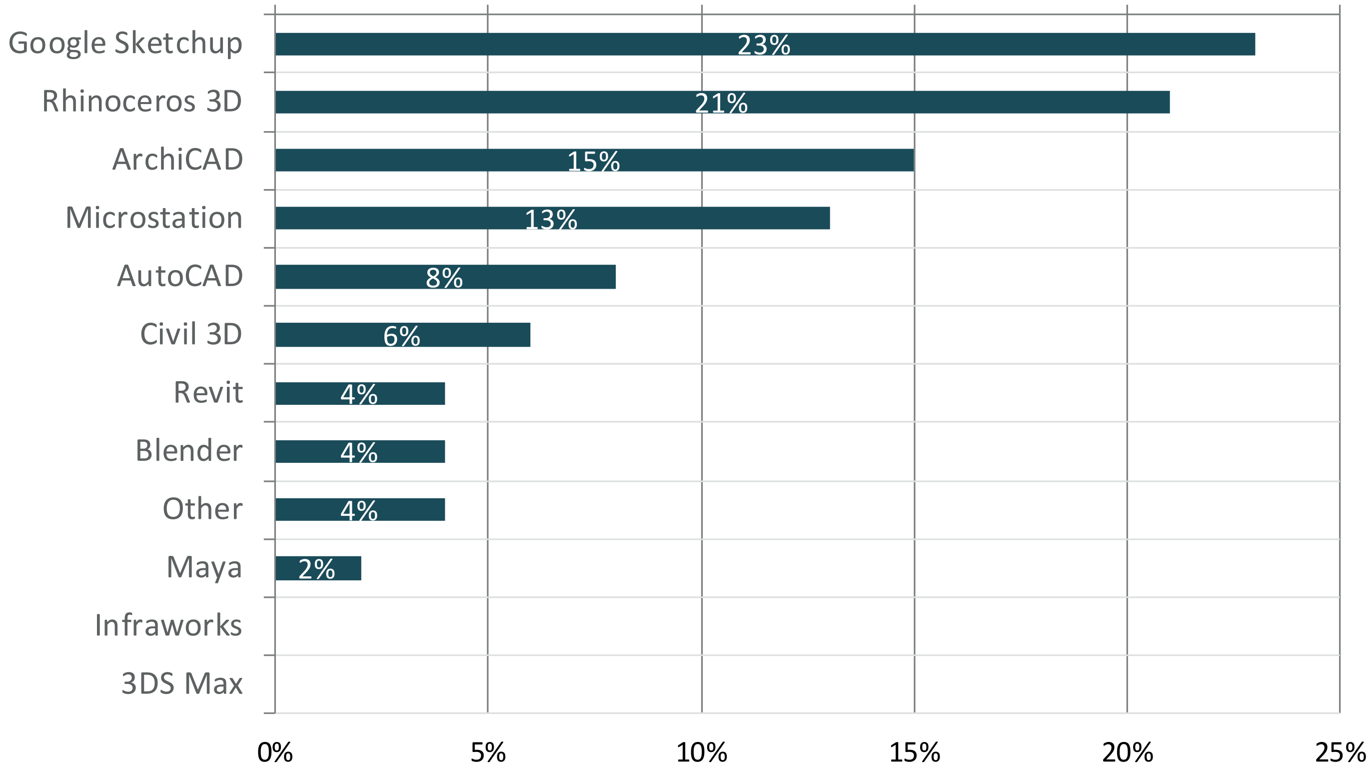


	Never used	Begin-ner	Inter-mediate	Better than aver-age	Expert	To-tal	Aver-age	Me-dian
Google Sketchup	7	18	16	9	2	52	1,63	2
	13,46%	34,61%	30,77%	17,31%	3,85%			
Rhinoceros 3D	21	17	10	3	1	52	0,96	1
	40,39%	32,69%	19,23%	5,77%	1,92%			
ArchiCAD	19	26	5	2	0	52	0,81	1
	36,54%	50%	9,61%	3,85%	0%			
Revit	36	14	2	0	0	52	0,35	0
	69,23%	26,92%	3,85%	0%	0%			
Infraworks	47	4	1	0	0	52	0,12	0
	90,39%	7,69%	1,92%	0%	0%			
Civil 3D	38	8	3	2	1	52	0,46	0
	73,08%	15,38%	5,77%	3,85%	1,92%			
3DS Max	44	8	0	0	0	52	0,15	0
	84,62%	15,38%	0%	0%	0%			
Maya	51	1	0	0	0	52	0,02	0
	98,08%	1,92%	0%	0%	0%			
Blender	46	4	0	2	0	52	0,19	0
	88,46%	7,69%	0%	3,85%	0%			
AutoCAD	16	18	9	8	1	52	1,23	1
	30,77%	34,62%	17,31%	15,38%	1,92%			
Microstation	26	12	13	1	0	52	0,79	0,5
	50%	23,08%	25%	1,92%	0%			
Other	42	4	2	4	0	52	0,38	0
	80,77%	7,69%	3,85%	7,69%	0%			
Total	393	134	61	31	5	624	0,59	0

Answers given into free text field

Option names	Text
Other	Lumion
Other	ei muita
Other	Cinema 4D
Other	VectorWorks Landmark
Other	VectorWorks
Other	(QGIS)
Other	-
Other	Novapoint 20.0
Other	Unreal

16. If you had to pick one software that you are most familiar with, which one would it be? Number of respondents: 52



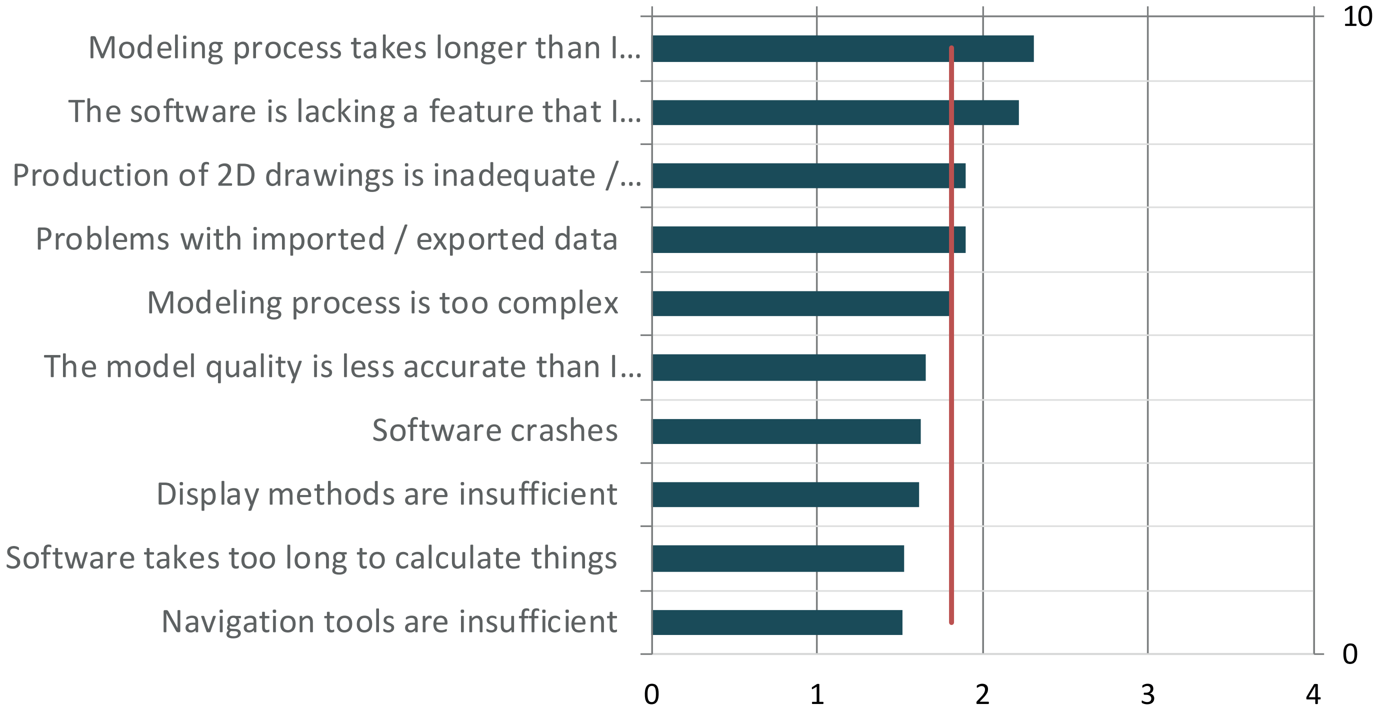
	n	Percent
Google Sketchup	12	23,08%
Rhinoceros 3D	11	21,15%
ArchiCAD	8	15,38%
Revit	2	3,85%
Infraworks	0	0%
Civil 3D	3	5,77%
3DS Max	0	0%
Maya	1	1,92%
Blender	2	3,85%
AutoCAD	4	7,69%
Microstation	7	13,46%
Other	2	3,85%

Answers given into free text field

Option names	Text
Other	Cinema 4D
Other	VectorWorks

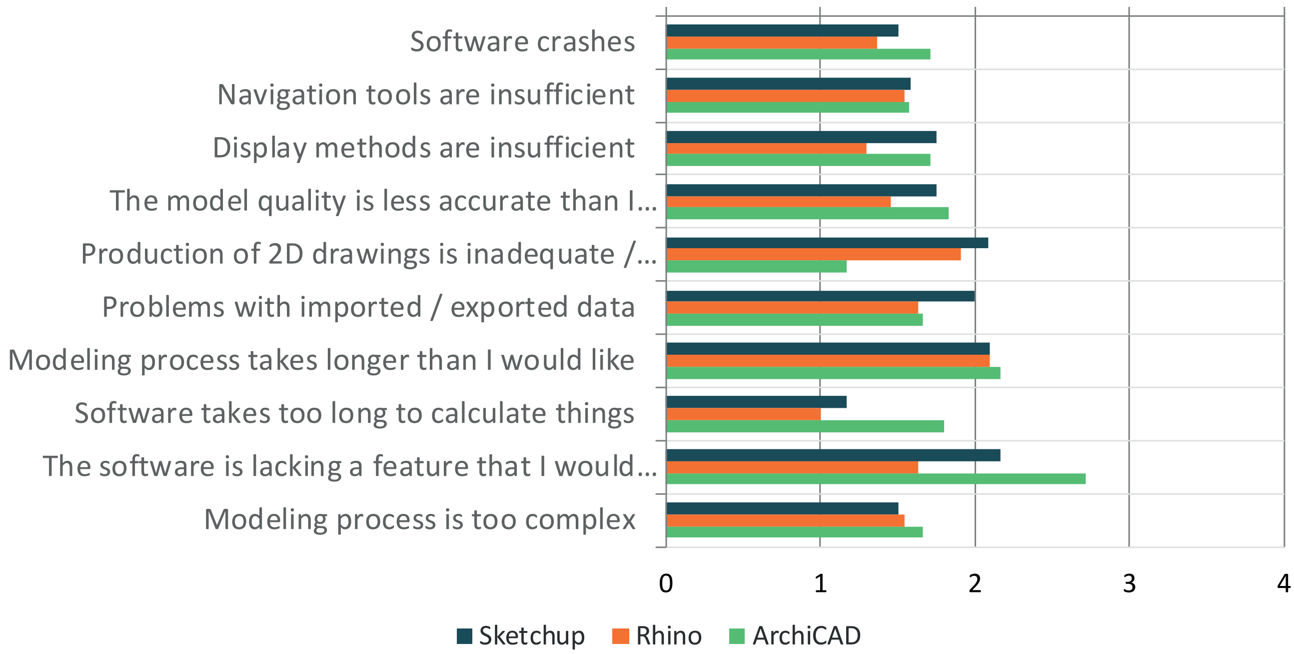
17. To which extent have the following been a problem with the software you are the most familiar with?

Number of respondents: 51



	never	a little of the time	some of the time	most of the time	all the time	Total	Aver-age	Medi-an
Software crashes	2	19	26	4	0	51	1,63	2
	3,92%	37,26%	50,98%	7,84%	0%			
Navigation tools are insufficient	5	21	17	7	0	50	1,52	1
	10%	42%	34%	14%	0%			
Display methods are insufficient	6	16	20	7	1	50	1,62	2
	12%	32%	40%	14%	2%			
The model quality is less accurate than I would prefer	7	15	18	8	2	50	1,66	2
	14%	30%	36%	16%	4%			
Production of 2D drawings is inadequate / too compli-cated	6	13	18	6	7	50	1,9	2
	12%	26%	36%	12%	14%			
Problems with imported / exported data	3	12	22	13	0	50	1,9	2
	6%	24%	44%	26%	0%			

Modeling process takes longer than I would like	2	9	18	12	8	49	2,31	2
	4,08%	18,37%	36,73%	24,49%	16,33%			
Software takes too long to calcu-late things	8	16	17	7	1	49	1,53	2
	16,33%	32,65%	34,69%	14,29%	2,04%			
The software is lacking a feature that I would like to have	1	15	14	14	7	51	2,22	2
	1,96%	29,41%	27,45%	27,45%	13,73%			
Modeling process is too complex	3	16	18	13	0	50	1,82	2
	6%	32%	36%	26%	0%			
Total	43	152	188	91	26	500	1,81	2



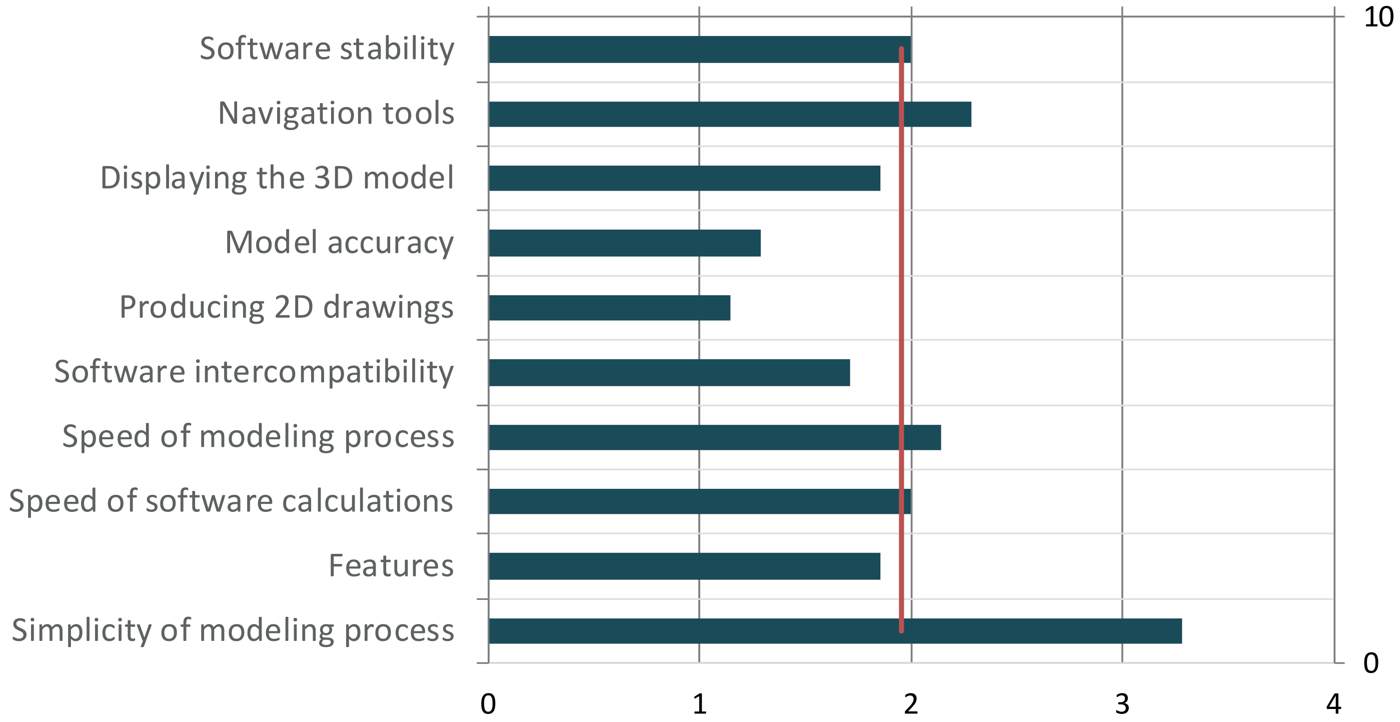
18. If you have encountered other problems, you can write them down here.

Number of respondents: 8

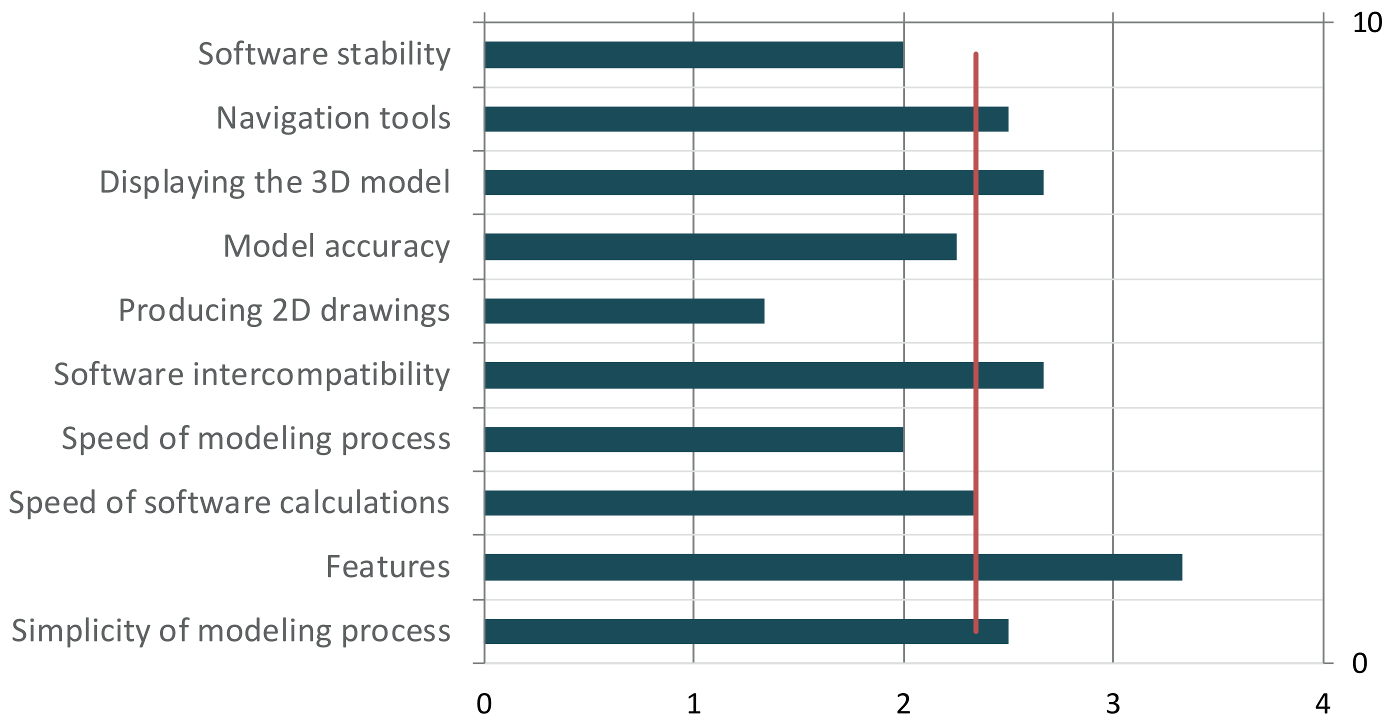
Responses
yhteensopivuus muiden ohjelmien kanssa/tiedostojen vaihto ohjelmien välillä
Microstationilla ifc-tiedoston tuottaminen ei onnistu
SketchUpissa objektit sulautuvat toisiinsa, mikä voi ohittaa komponenteilla (ei aina). Lisäksi maastonmuotoiluun menee tuhottomasti aikaa, varsinkin eri jäänteiden siistimiseen. Ohjelman 3D tuotosten export ja import toiseen ohjelmistoon (esim. Microstation) tutkitaan.
En osaa käyttää mallinnusohjelmia tarpeeksi hyvin. Opettelemiseen menee paljon aikaa.
(Olen käyttänyt Archicadia töissä käytännössä vain 2D-piirtämiseen, joten minulla ei ole edelliseen kohtaan antaa juurikaan vastauksia.)
Mesh olisi tarkin kuva maisemasta, mutta meshin muokkaaminen on tehty todella vaikeaksi. Jos mesh on liian iso (mikä se monessa tilanteessa maisemasuunnittelussa on), sitä ei pysty leikkaamaan tai muokkaamaan halutuksi. Silloin on turvauduttava epätarkkoihin ratkaisuihin ja työkaluihin, mikä taas ei ole toivottua.
Pinnasta tehtäviin leikkauksiin ei ei saa automaattisesti projisoitua objekteja.
Yhteensopivuus muiden 3d-tiedostojen kanssa.

19. How do you think the software compares to other 3D modeling software? (If you cannot compare, you can leave this empty)

Google Sketchup
Number of respondents: 7



Rhinoceros 3D
Number of respondents: 5



20. In what kinds of projects have you used 3D modeling the most? How about the least? You can use examples.

Number of respondents: 36

Responses
kilpailu, projekti jossa on pitänyt tuottaa visualisointeja
kaupunkisuunnittelu ja pihasuunnittelu
the most: Competitions the least: realisation projects for cities
Eniten piha- ja puistosuunnittelussa, yleensä sitä enemmän mitä tarkemman mittakaavan työsktentelystä on kyse.
Puistosuunnittelussa eniten
Infrahankkeissa, yhteistyöhankkeissa rakennussuunnittelun kanssa
Enimmäkseen väylä- ja aluesuunnittelukohteissa. Esimerkiksi asemakaava-alueiden kunnallisteknisessa suunnittelussa jokainen hanke on jossain määrin 3d-mallinetaan. Näissä 3d-mallit ovat erittäin hyödyllisiä ensisijaisesesti teknisestä näkökulmasta. Maisemasuunnittelun näkökulmasta hyviä kohteita ovat puistosuunnittelun kohteet, joissa esimerkiksi maastomuotoilulla haetaan esteettisesiä ratkaisuja.
Omien opiskelujuttujen osa-alueiden mallintaminen. Joissain työprojekteissa pitää mallintaa oikeille paikoilleeen aitoja, portaita yms. pihaelementtejä, ja joku muu tekee lopun mallin. Toisinaan on töissä mallinnettu maastoa/hyödynnetty jonkkun muun tekemää maastomallia esim. leikkausten pohjaksi.
Laaja-alaisissa ja monimuotoisissa. Kaikkein eniten hybridihankkeissa.
Kouluprojekteissa, jossa en ole päässyt käymään paikan päällä ja ympäristö on hankalasti hahmotettava ilman mallinnusta. Jos täytyy saada hyvät näkymäkuvat eikä ole valokuvaa pohjaksi, mallintamisesta on hyötyä. Töissä olen käyttänyt mallinnuksia lähinnä leikkausten ja näkymäkuvien pohjaksi. Jos ei ole ollut mallia, teen ne alusta asti manuaalisesti.
Koulussa, kun haluan piirtää tarkan havainnekuvan, kun haluan saada perspektiivin oikein. Töissä ei ole ollut käyttöä.
sellaisissa joissa on maastossa paljon korkeuseroja
3D-mallinnusta on ollut vain kolmessa hankkeessani: yksi oli koulun piha, yksi katualue, jossa mallinnettiin vapaamuotoiset meluvallit. Kolmannessa mallinneettiin kiertoliittymien keskiaiheita.
Eniten koulutöissä, joissa täytyy suunnitella jotain (kuten puisto, rakennus tai asuinalue) ja suunnitelmat täytyy esittää tarkasti monilla kuvilla. Vähiten koulutöissä, joissa suunnitelmat saa olla suurpiirteisiä, eikä niistä vaadita tarkkoja piirrustuksia/kuvia.
Eniten olen käyttänyt hankalasti hahmoteltavien, esim. monimutkaisten rakenteiden mallintamisessa. Myös visualisoidessa suunnitelmia käytän 3D-mallinnusta usein. Vähiten käytän helpoissa töissä, jotka ei miltäkään taholta (minä itse, asiakas, yhteistyökumppanit) vaadi 3D:tä.

Suunnitelman osa-alueen ulkonäön hahmottaminen ja maastomallinnus ja suunnitelman yhteensovitus olemassaolevaan.
Koulutöissä. Ammattimaailmassa 3D:tä ei ole vielä koskaan vaadittu maisema-arkkitehtiprojekteissa.
En ole käyttänyt kuin opiskellessa tai omissa projekteissa. Töissä ainoastaan olen tuottanut pinnanmuotoilusta 3d-dataa liitettäväksi arkkitehdin malliin. Tätäkäin harvoin.
Eniten: Puistojen ja kaupunkitilan luonnostelu, toteutussuunnittelua edeltävä vaihe, varsinkin maastomallinnus ja rakennusvolyymit; Vähiten: maisema-analyysi ja toteutuspiirustukset
Kaupunkisuunnittelussa, jossa on tärkeää saada rakennusten massat mukaan suunitelmaan
Eniten yleissuunnitelmatasoisissa hankkeissa
interaktiivisissa esittelymalleissa (pelimallit)
Pieni mittakaavaisissa suunnitteluprojekteissa.
Kaupunkisuunnittelun kursseilla, jossa on helppo nostaa yhsinkertaisia kantikkaita laatikoita taloiksi ja esim kerroskorkeudet ja teiden leveydet on helppo piirtää heti oikeassa mitassa. Maiseman kurssien puistomaisemmissa suunnitelmissa 3D-malli ei ole tuntunut yhtä välttämättömältä, etenkin, kun maastonmuokkaus on Rhinollakin niin hirveää, että mieluummin välttää ohjelmaan koskemista kokonaan ja piirtää käsin.
eniten: aikoinaan kouluprojekteissa “räkä”-malleja hahmottamaan tilallisuutta ja näkymäkuvien pohjaksi vähiten: en osaa vastata
Julkisille alueille rakentuvissa kohteissa. Niissä ‘yleisö’ on laaja ja yhteistyökuviot laajat.
Opinnoissa Digital Landscape kurssilla ja YKS:n kursseilla studioissa (töissä asemakaavaprojekteissa)
Olen mallintanut suuren puiston pintoja kokonaisuudessaan rakennussuunnitteluvaiheessa
Blenderiä maisemaelementtien muotoilussa. SketchUppia ja Rhinoa pihasuunnitelmien ja kaupunkisuunnitelmien mallintamisessa. Vähiten projekteissa, joissa riittää vain pohjakuva ja leikkaukset, ja sellaisissa projekteissa, joiden maastoa ei pysty kunnolla mallintaa. Eniten olen käyttänyt 3d-ohjelmia projekteissa, joissa on selkeitä tasoja, esim portaita, kiveyksiä.
Opisekellessa eniten, koska oli aikaa kokeilla. Töissä projekteissa, joissa on paljon rakenteellisia haasteita (jos on aikaa) ja lisäksi prjekteissa, jossa mallia tilataan, joka on harvoin.
Koulussa perusteita esim Sketch Up
Laajat aluehankkeet, yleis-, puisto- ja katusuunnittelu
Kerrostalokorttelin toteutussuunnittelu
Suuremmissa maisemasuunnitteluissa

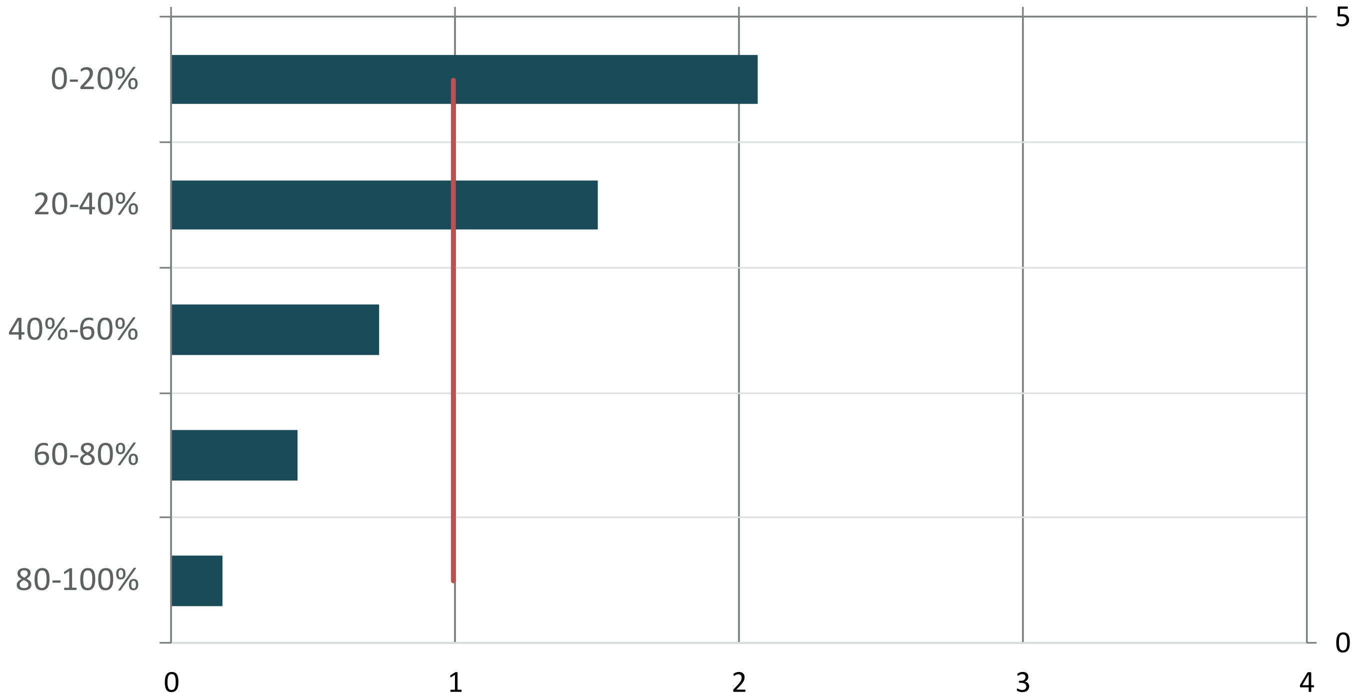
Erilaisten kaupunkipuistojen ja -aukioiden suunnitelmien mallintamisessa eniten, juuri näkymäkuvien pohjaksi. Vähiten runsasta kasvillisuutta sisältävissä suunnitelmissa, koska siihen monet ohjelmat ovat melko kykenemättömiä, vaikka kaiketi joitain ihan hyviä plug-ineja on ohjelmille olemassa.
Eniten:hulevesiuoman tai lammen suunnittelu, maastonmuotoilu Vähiten:Tasaisille alueille suunnitellut puistot esim. liikuntapuistot

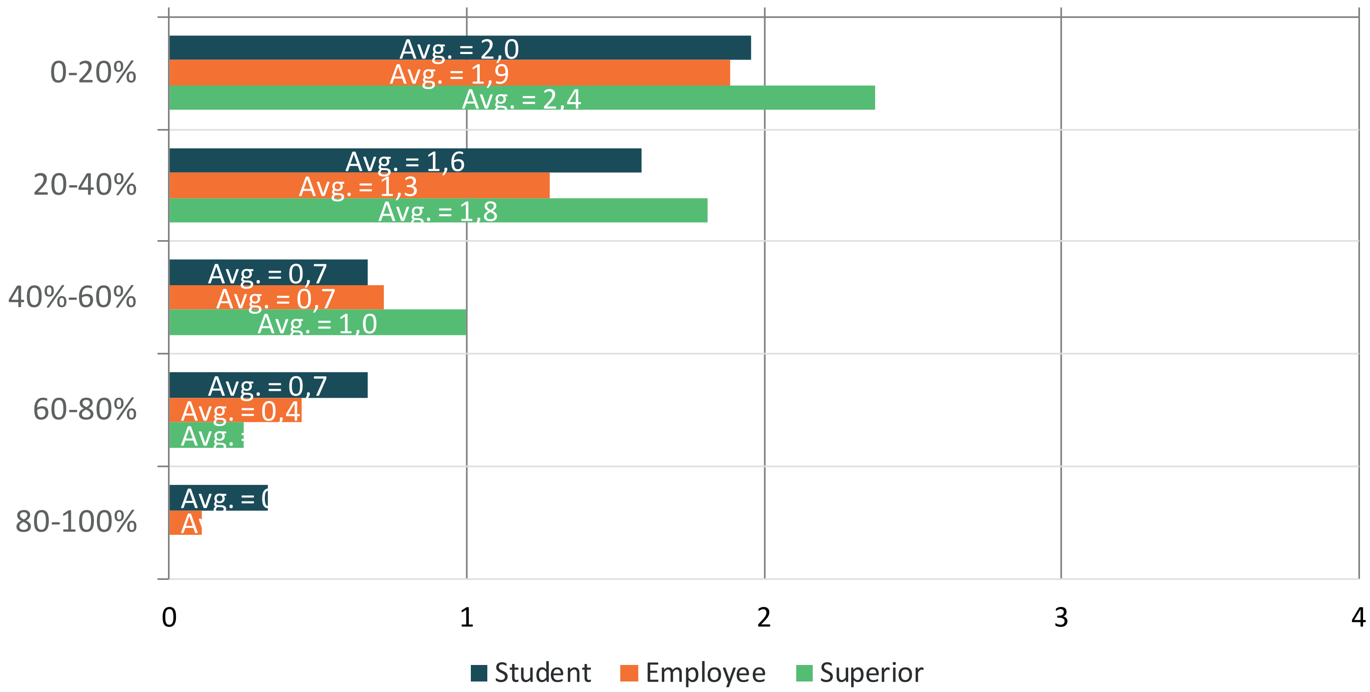
21. What percentage of work hours do you estimate is spent on 3D modeling in different kinds of projects? You can use examples.

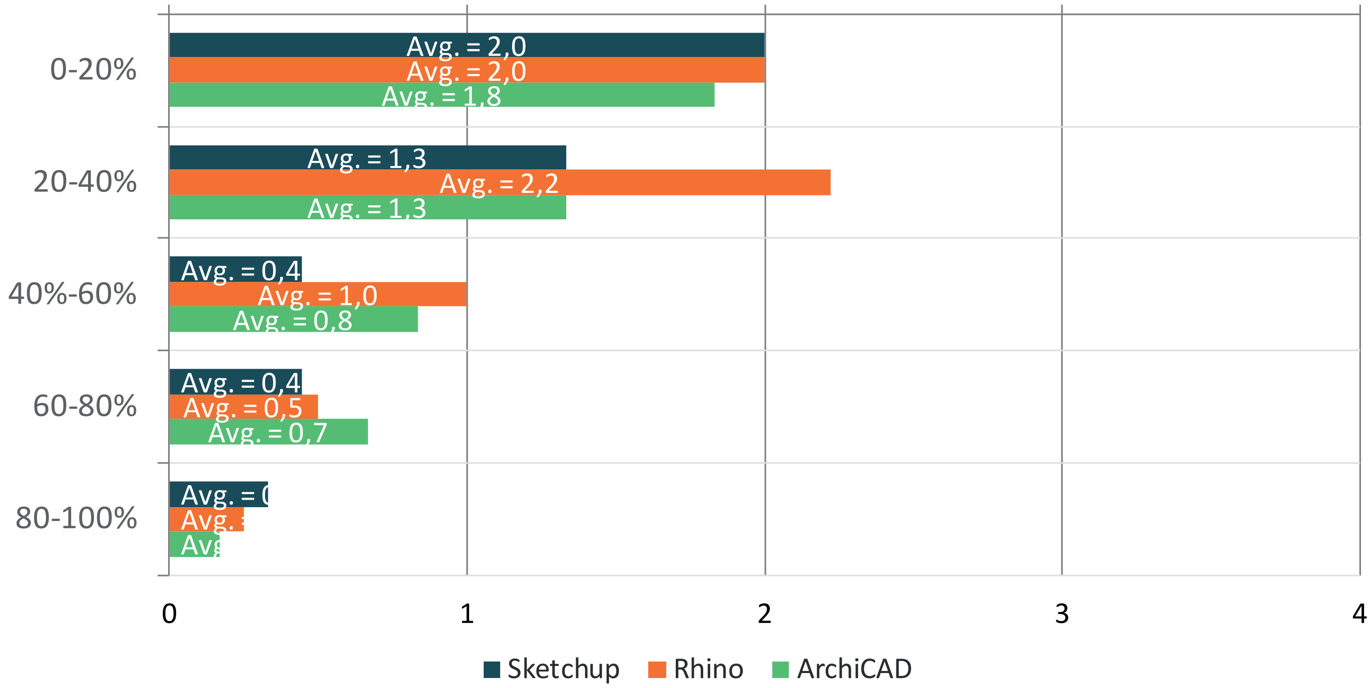
Number of respondents: 12

Responses
20%, on samalla suunnittelua
20-30%
Väyläsuunnittelun puolella mallia tehdään tavallaan koko suunnittelun ajan, joten mallintamiselle on aidosti vaikea haarukoida omaa tuntimenekkiä. Karkeasti siis suunnittelu on mallintamista. Maisemasuunnittelun puolella sen sijaan mallintaminen tehdään vielä toistaiseksi erillisenä osana ja mikäli hankkeesta päätetään tehdä malli, niin “hiha-arviona” arvioisin, että noin 25% ajasta menee puhtaasti visuaalisen puistosuunnitelman aikaan saamiseksi. Tämä tosin perustuu vain parin pienehkön puistosuunnitelman otantaan.
Aika vähän.
hankala arvioida mutta voi mennä aika kauankin. n 10%
Pystyn sanomaan vain yhdestä projektista. Siinä meni n. 1/5 hankkeen tunneista. Muissa hankkeissa en ole ollut projektipäällikkönä vaan maisemaosuuden vastuusuunnittelijana.
Joskus jopa puolet työajasta. Suunnitelman visualisoiminen asiakkaalle on oma työvaiheensa, joka vie aikaa.
Vaihtelee
ehkä 5%
30
Riippuu täysin suunnittelutasosta 10-20%
Esim. hulevesiuoman mallinnus 20-25% työtunneista

22. How often do you estimate the following percentage of time in the design process is spent on 3D modeling in your design projects? Number of respondents: 47



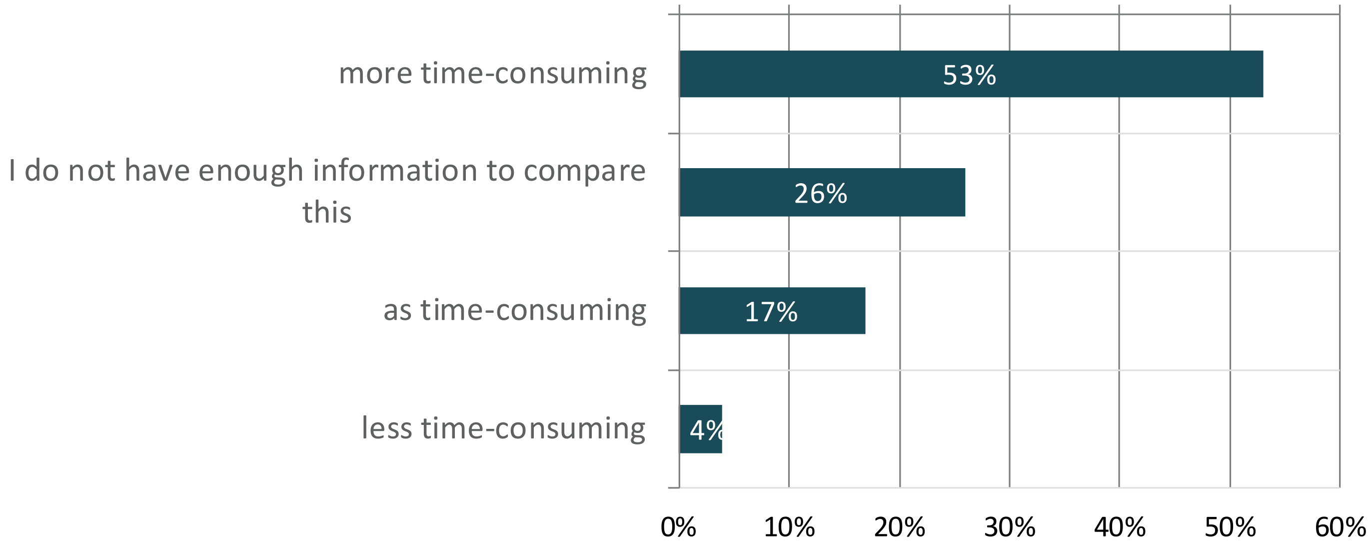


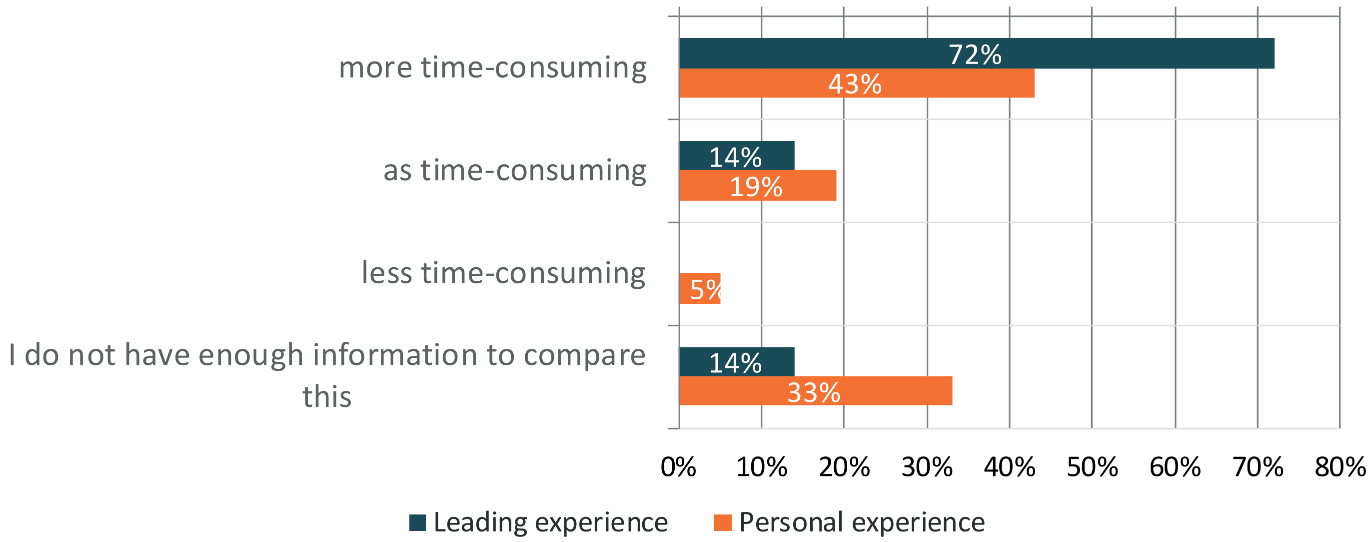


	Never	Rarely	Sometimes	Often	Always	Total	Aver-age	Medi-an
0-20%	5	9	14	14	4	46	2,07	2
	10,87%	19,57%	30,43%	30,43%	8,7%			
20-40%	9	12	19	5	1	46	1,5	2
	19,57%	26,09%	41,3%	10,87%	2,17%			
40%-60%	25	11	5	4	0	45	0,73	0
	55,56%	24,44%	11,11%	8,89%	0%			
60-80%	34	5	4	1	1	45	0,44	0
	75,56%	11,11%	8,89%	2,22%	2,22%			
80-100%	40	3	1	1	0	45	0,18	0
	88,89%	6,67%	2,22%	2,22%	0%			
Total	113	40	43	25	6	227	0,99	1

23. Please compare how much time was spent on similar projects with the most and least 3D modeling. Would you say the project with more 3D modeling in comparison to the one with less 3D modeling was:

Number of respondents: 47





	n	Percent
more time-consuming	25	53,19%
as time-consuming	8	17,02%
less time-consuming	2	4,26%
I do not have enough information to compare this	12	25,53%

24. Why did the project with more 3D modeling take more or less time?

Number of respondents: 25

Responses
Kului yhtä paljon, sillä mallinnus vie aikaa, mutta säästää toisaalta aikaa esimerkiksi 2D-kuvien tekemisessä. Jos suunnittelussa on tarkkoja ja erityisiä yksityiskohtia, aikaa kuluu 3D-mallin avulla jopa vähemmän kuin ilman mallinnusta.
Lisätiedot, muutosten hitaus
Mallintamisessa detaljien ja rajakohtien suunnittelu vaatii aivan oman työvaiheensa, kun taas perinteisessä “asemapiirustus ja leikkausesitykset” -suunnittelussa nämä pystytään oikomaan esimerkiski periaateratkaisuin.
Jos mallin tekee edes keskinkertaisesti, siitä saa hyvät havainnekuvapohjat.
Vastaantulevat ongelmat 3D-mallinnuksessa vievät paljon aikaa selvittää. Asiat ovat monimutkaisia, varsinkin kun ei ymmärrä vielä paljon ohjelman toiminnasta.
työvaiheita on enemmän
Minulla on vain vähän kokemusta hankkeista, joissa mallinnusta mukana. Riippuu hankkeista ja missä vaiheessa mallinnusta tehdään. Aikaa saattaa säästyä, jos mallintamista käytetään suunnittelun tukena ja ongelmat ratkaistaan mallintamisen avulla. Parissa hankkeessa mallinnus tehtiin vasta lopuksi ikään kuin ylimääräisenä osana. Tosin joitakin ongelmakohtia löytyi sitä kautta.
Koska 3D-mallinnusta vaativat projektit tai kurssit vaativat muutenkin enemmän työtä ja koska en osaa kovin hyvin vielä 3D-mallinnusta.
3D-mallintaminen on huomattavasti enemmän aikaa vievää ja monimutkaisempaa kuin 2D-piirtäminen.
2D -mallinnuksessa saa tehtyä hyvinkin tarkkaa työtä kaksiulotteisesti. Heti kun otetaan mukaan kolmas ulottuvuus, projekti vaatii enemmän työtä jotta lopputulos olisi edelleen mittatarkka.
Jos asiaa pääsääntöisesti ei tee, kuluu enemmän aikaa. Teen käytännössä töitä pienellä kannettavalla 2d:nä, laskentatehoja ei ole kovin raskaisiin malleihin.
Projekti, jossa mallinnusta on ollut mukana, on ollut hyvin erityyppinen sisällöltään ja tavoitteitaan, kuin ei-mallinnusprojekti, joten vertailu on vaikeaa
Ympäristön esittäminen kolmiulotteisesti on tietysti monimutkaisempaa kuin kaksiulotteisesti. Etenkin kasvillisuuden 3d-visualisoinnissa on edelleen suuria haasteita.
3D-mallinnus nopeuttaa työtä, sillä samalla voi muokata pohjaa, leikkauksia ja rendauksia. Mikäli ohjelma ei ole tuttu ja opetteluun menee paljon aikaa voi asia tosin olla myös toisin päin.
Työmäärä pysyy ehkä lopulta suht samoissa.
vaikea suunnittelukohde, tai muuten iso projekti
-
Aikaa kuluu enemmän, kun ohjelma on käyttäjälle uusi, työkalut ovat osin puutteelliset ja mallintamiseen ei ole vielä kehitetty selkeitä työnkulkuja. Kaikki on siis käytännössä kokeilemista yrityksen ja erehdyksen kautta.

Ohjelmaa (sketchup) oli vaikea käyttää maaston mallintamiseen, ja ei sopinut kovin hyvin esim kasvien määrittelyyn, joten tuli käytettyä turhaa aikaa ”oikean” värin valintaan materiaaliksi ym.
Suunnittelupäätösten tekemiseen kuuluu jokatapauksessa yhtäpaljon aikaa.
Suunnitelmamuutokset 3D mailmassa vievät enemmän aikaa, ohjelmat eivät ole vielä kovin kehittyneet
Mallia piti päivittää mutta siitä ei ollut hyötyä, ei ollut tarpeeksi tarkka
Mallista on helppo saada muita kuvia ”ulos”
En osaa itse varsinaisesti arvioida, koska teen opiskelijana töitä vain osa-aikaisesti, joten en pysty hahmottamaan kovin tarkasti kuinka paljon eri projekteissa menee aika eri vaiheisiin, etenkin kun projekteissa työskentelee useampia henkilöitä.
Jos on rakennussuunnitteluprojekti niin tällöin pitää saada tehtyä myös tarkat mitoitetut, korkotiedoilla varustetut 2D-kuvatkin. 3D-malleja varten tarvitaan vähintään luonnokset 2D:ssä jotta tiedetään tilavaraukset ja mitat. Ja sitten niistä 3D-malleista pitää viilata lopulliset 2D piirustukset. Tuntuu että vaiheita on enemmän ja niitä pitää tehdä eri ohjelmilla. Eri toimialat on tottuneet käyttämään eri ohjelmia, joten sekin voi tuoda lisäongelmia.

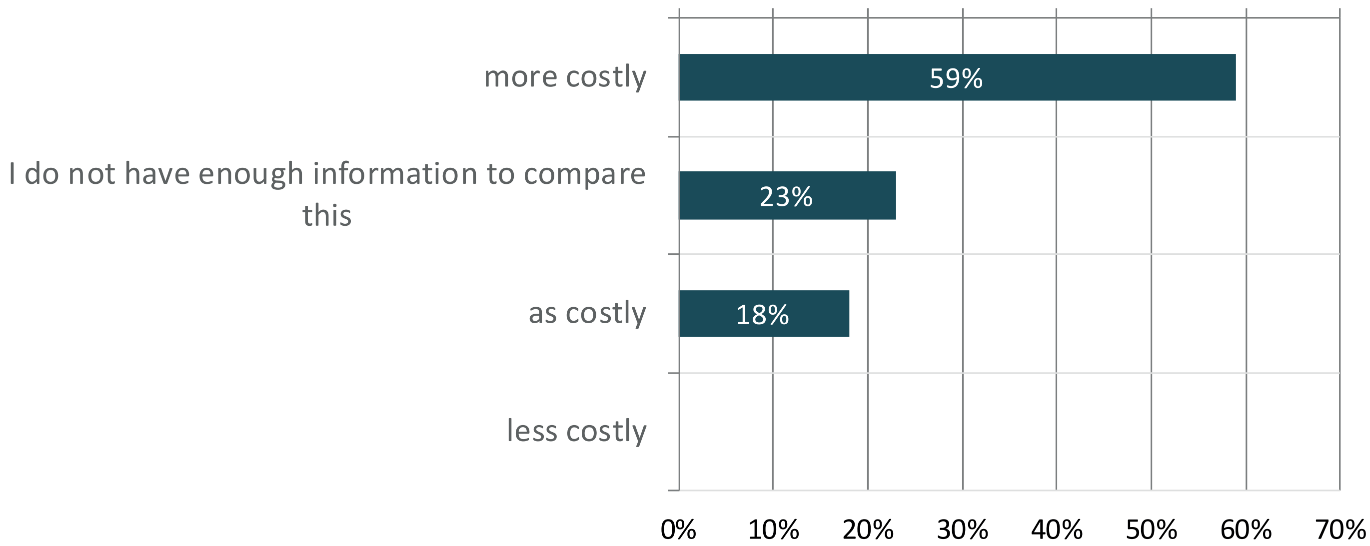
25. What are the expenses of the 3D modeling software your company uses?

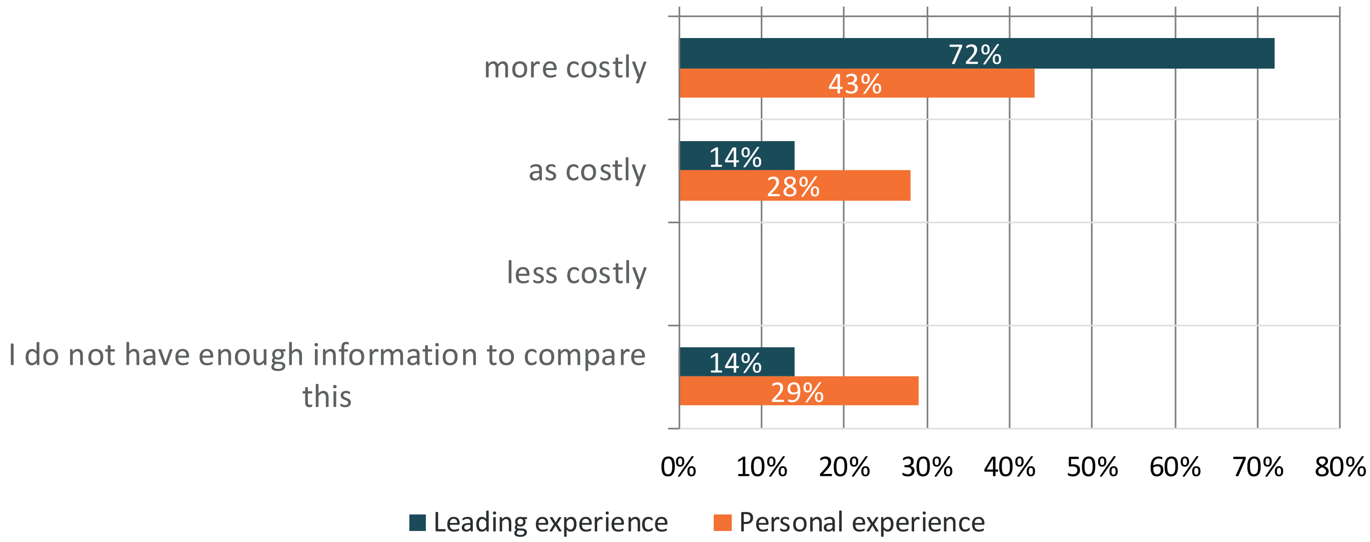
Number of respondents: 6

Responses
Tällä hetkellä toimistolla käytössä ArchiCAD joka on melko kallis
50e/kk/hlö
Perussuunnitteluohjelmat sisältävät riittävät ja tarvittavat 3D-työkalut tarkoituksiimme. Lisätoiminnoista tosin syntyy pienehkö lisäkulu. Varsinaisia summia tai osuuksia kokonaissummasta en osaa arvioida.
n. 5t€/vuosi / lisenssi - toki osassa paketteja tulee monta ohjelmaa.
n.2000 e
Lisenssi hankittu aikoinaan, maksoi jonkun satasen

26. Please compare the costs of similar projects with the most and least 3D modeling. Would you say the project with more 3D modeling in comparison to the one with less 3D modeling was:

Number of respondents: 17

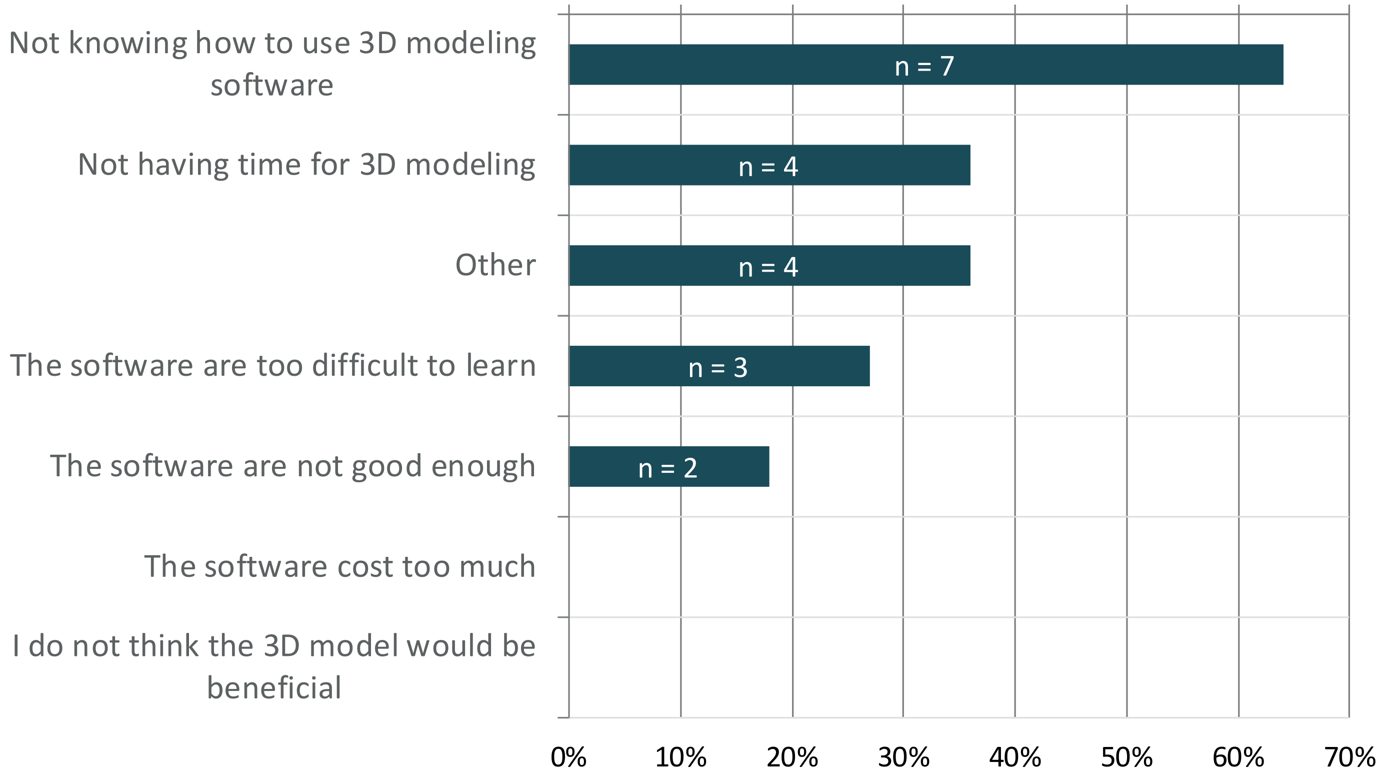




	n	Percent
more costly	10	58,82%
as costly	3	17,65%
less costly	0	0%
I do not have enough information to compare this	4	23,53%

27. What are the reasons you have not used a 3D model in a landscape architecture project?

Number of respondents: 11, selected answers: 20



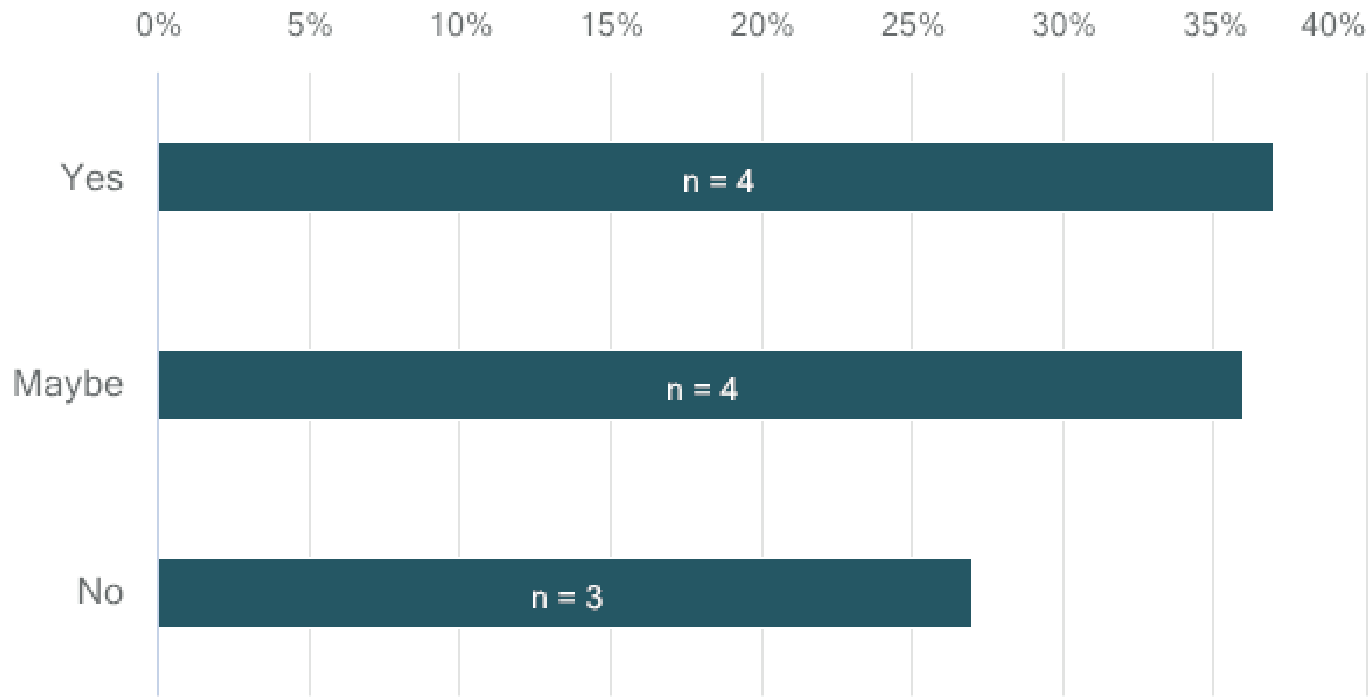
	n	Percent
Not knowing how to use 3D modeling software	7	63,64%
Not having time for 3D modeling	4	36,36%
The software are too difficult to learn	3	27,27%
The software are not good enough	2	18,18%
The software cost too much	0	0%
I do not think the 3D model would be beneficial	0	0%
Other	4	36,36%

Answers given into free text field

Option names	Text
Other	Tilaajilta ei myöskään ole tähän asti ollut kiinnostusta
Other	En ole vielä kerennyt aloittaa niiden opiskelemista opintojen ohella.
Other	Minun aktiiviaikanani ojelmia ei vielä ollut, eikä ole ollut tilaisuutta opetella
Other	olen nyt pois tyoelamasta

28. Would you like to use a 3D model in the future?

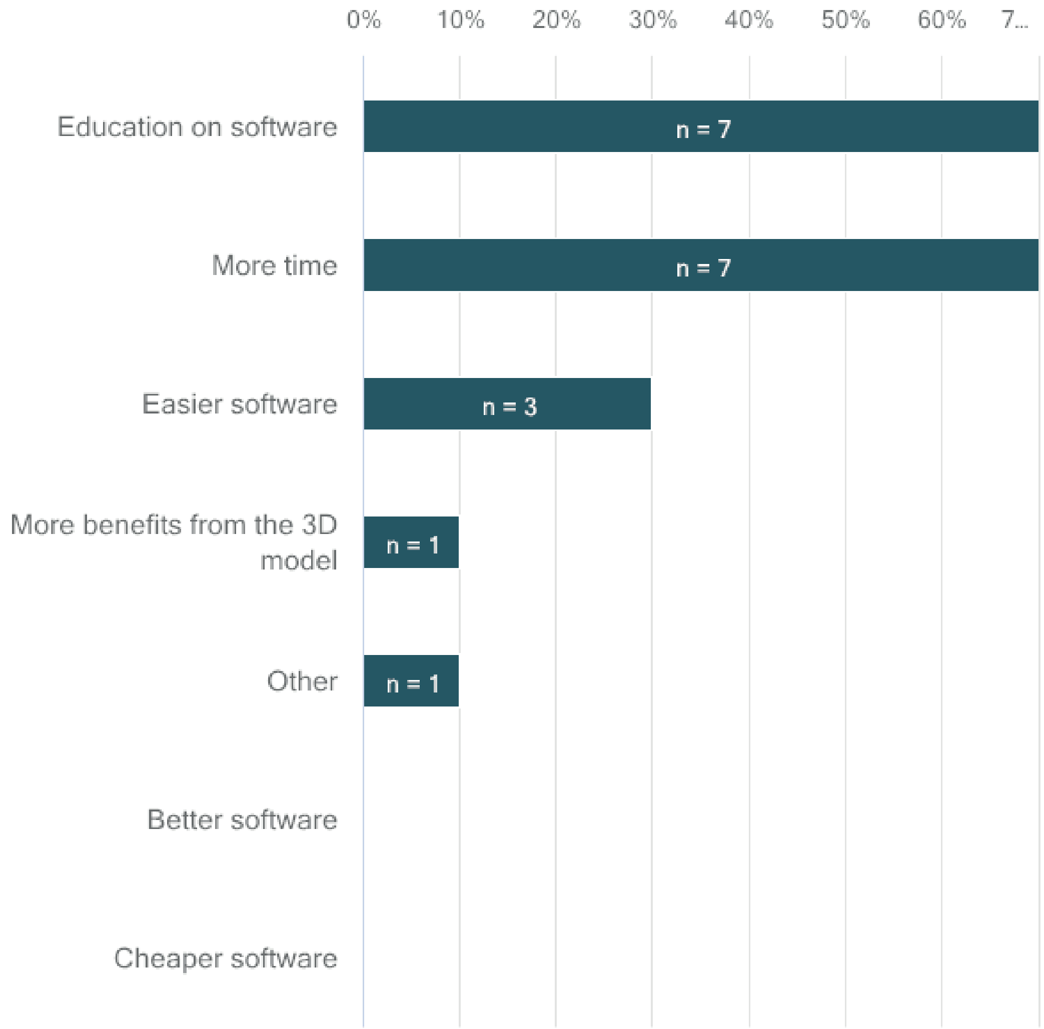
Number of respondents: 11



	n	Percent
Yes	4	36,37%
Maybe	4	36,36%
No	3	27,27%

29. What do you think would be required for you to use 3D models in the future?

Number of respondents: 10, selected answers: 19



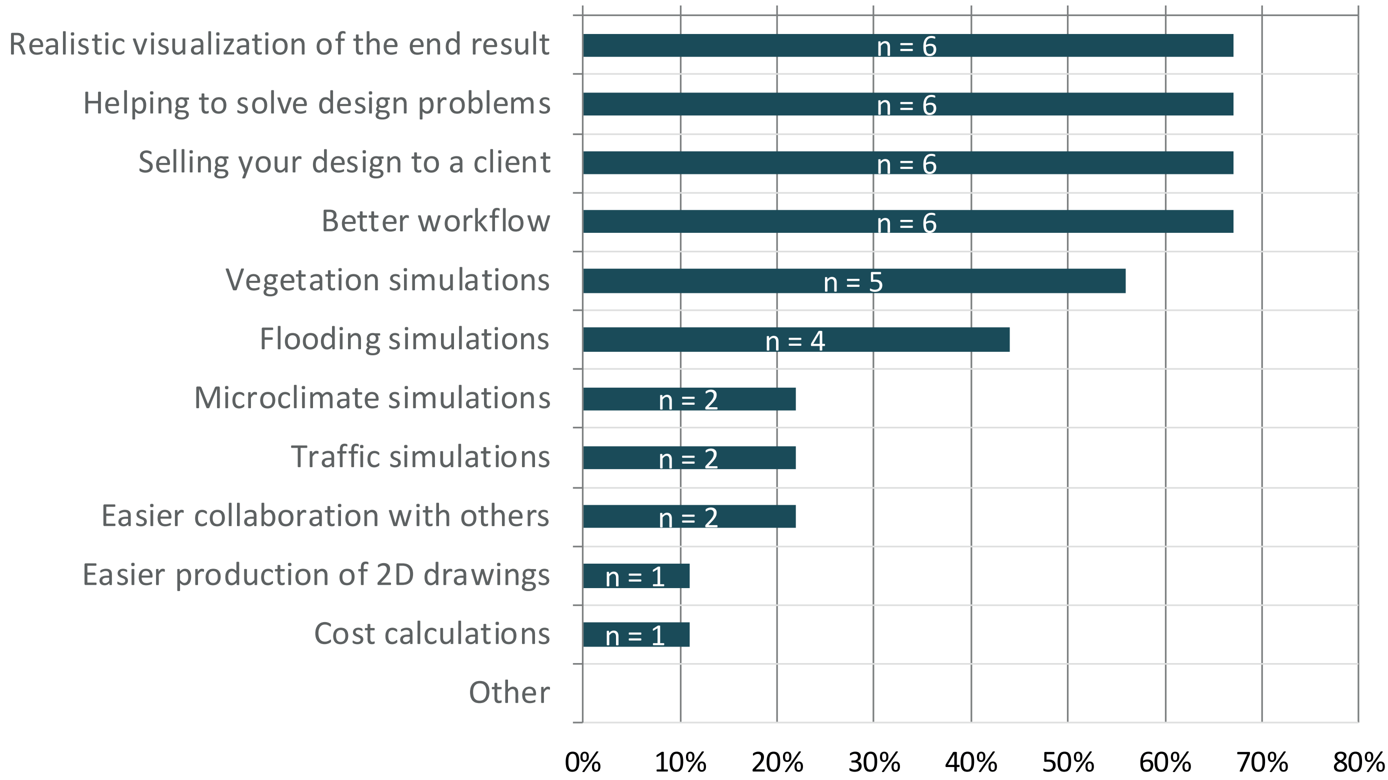
	n	Percent
Education on software	7	70%
More time	7	70%
Easier software	3	30%
Better software	0	0%
Cheaper software	0	0%
More benefits from the 3D model	1	10%
Other	1	10%

Answers given into free text field

Option names	Text
Other	Tilaajan intressi, ohjelmien haastavuudesta en osaa sanoa, sillä en ole käyttänyt niitä aikoihin

30. What benefits would you like to get from a 3D model?

Number of respondents: 9, selected answers: 41



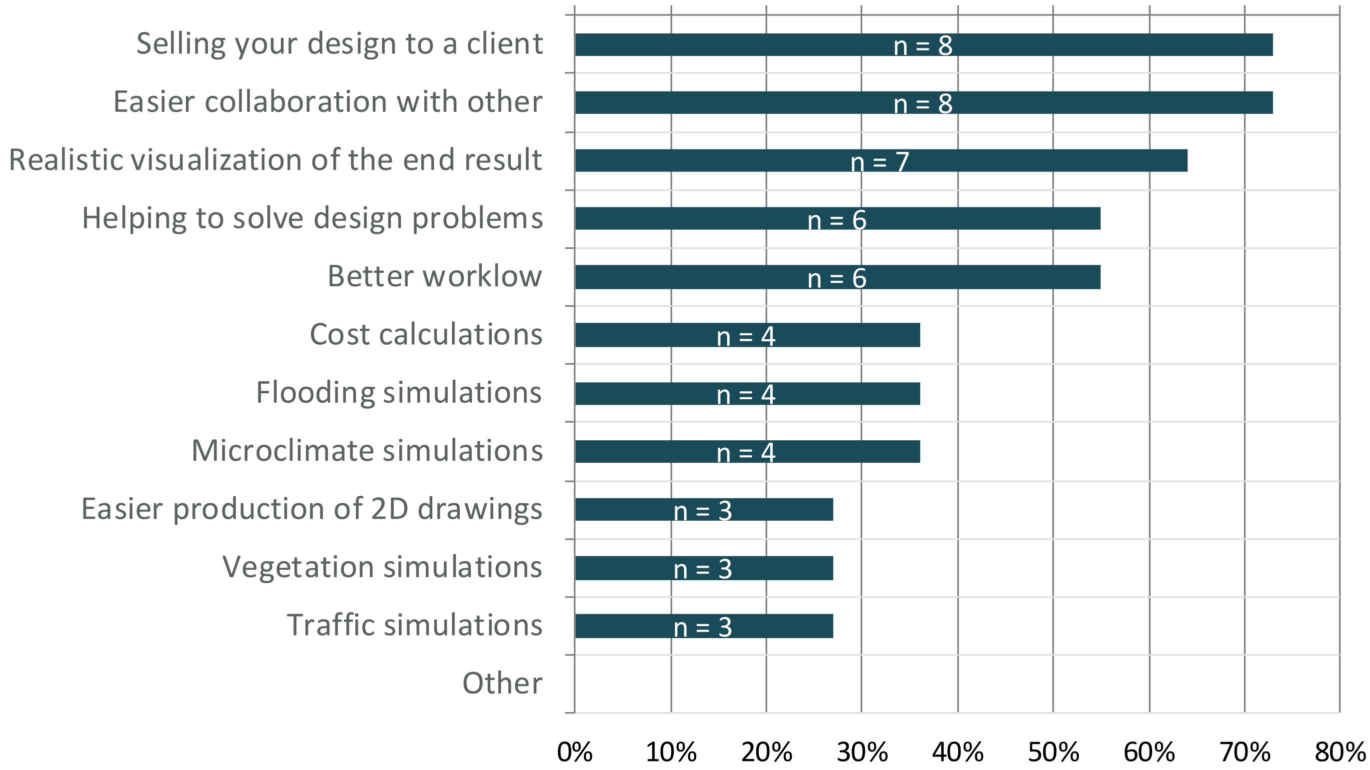
	n	Percent
Easier production of 2D drawings	1	11,11%
Realistic visualization of the end result	6	66,67%
Helping to solve design problems	6	66,67%
Selling your design to a client	6	66,67%
Cost calculations	1	11,11%
Better workflow	6	66,67%
Flooding simulations	4	44,44%
Vegetation simulations	5	55,56%
Microclimate simulations	2	22,22%
Traffic simulations	2	22,22%
Other	0	0%
Easier collaboration with others	2	22,22%

Answers given into free text field

Option names	Text

31. What benefits do you think you might get from a 3D model?

Number of respondents: 11, selected answers: 56



	n	Percent
Easier production of 2D drawings	3	27,27%
Realistic visualization of the end result	7	63,64%
Helping to solve design problems	6	54,55%
Selling your design to a client	8	72,73%
Cost calculations	4	36,36%
Easier collaboration with other	8	72,73%
Better worklow	6	54,55%
Flooding simulations	4	36,36%
Vegetation simulations	3	27,27%
Microclimate simulations	4	36,36%
Traffic simulations	3	27,27%
Other	0	0%

Answers given into free text field

Option names	Text

32. If you do not think you would get any benefits from a 3D model, why?

Number of respondents: 2

Responses
uskon että 3D- mallintaminen sopii tietynlaisiin projekteihin, sellaisiin joissa on haasteita ja ovat laajoja. Epäilen sen hyöty vs. kustannussuhdetta pienissä hank-keissa, joissa ei ole haasteita
Olen nyt siirtynyt elakkeelle, mutta aikaisemmin ei ollut aikaa oppia tekniikkaa, kun se tuntui aika vaativalta nyt varmaan yrittaisin uudelleen, jos viela olisi tarvetta

33. Any other comments

Number of respondents: 27

Responses
Lisää opetusta! ArchiCAD-opetusta Aaltoon
Todella kiinnostava diplomityön aihe, odotan innolla tutkimuksen tuloksia :)
Käytetään tottakai!
Painottaisin, että itse olen väyläsuunnitteluoppinut projektipäällikkö, en maisemasuunnittelija (joskin työskentelen maisemasuunnittelijoiden kanssa), joten vastauksiini on syytä suhtautua sen mukaisesti.
3opetuksen tulisi olla räätälöity juuri maisema-arkkitehtuuriin sopivaksi jotta sen oppiminen olisi helpompaa, siihen pitäisi myös sovittaa tilaajan interessit ja heidän mallintamiseen liittyvät toiveensa.
Mielelläni lukisin työsi, kun se valmistuu.
Ohjelmat pitää opetella itse, siksi mielimmin koulutöissä käyttää vain 2D kuvia, koska ne ovat tutumpia ja nopeampia tuottaa.
Uudella työpaikalla käytetään Infraworksia ja Civil3D -ohjelmia, jotka mielelläni halausiin oppia. Aiemmin töissä käytössä oli vain Archicad, joka taipuu usein tuskastuttavan huonosti pihojen tai minkään kasvillisuutta sisältävän laajemman alueen mallintamiseen. Osaltaan siksi mallintamista on tullut tehtyä hyvin vähän töissä. Useimmissa projekteissa ei edes pyydetä mitään mallinnusta, joten eipä silloin 3d:tä tule edes hyödynnettyä.
TUota 3d-mallinnuksen suhdetta kustannuksiin ei täysin voi verrata. Monesti myös sisältöä on tullut lisää / se on vaihtunut.
Yliopistossa opetus on ollut todella vajaata. Toivon että diplomityösi parantaa tilannetta.
Maisema-arkkitehdit ei tunnetusti hyödynnä 3D-mallintamisen mahdollisuuksia. Joskus ajatus pelkästään yläkuvien perusteella suunnitellusta ympäristöstä hirvittää. Mutta erityisesti alan vanhempi polvi on kuitenkin taitavia hahmottamaan asioita kolmiulotteisesti pelkkien 2D-piirustusten pohjalta. Lisäksi iso osa maisema-arkkitehtuuria on korkomaailma, joka esitettynä pelkästään 2D-piirustuksina tai leikkauksina ei aina anna tarpeeksi kattavaa kuvaa siitä asiakkaille tai edes suunnittelijalle itselleen. Helpoin tapa tutustuttaa maisema-arkkitehdit 3D:n maailmaan on Auocad-ohjelma. Se on käytössä monessa toimistossa, mutta yleensä vain light-versiona, josta puuttuu kaikki 3D-ominaisuudet. Jos käytössä olisi ohjelman täysi versio (jossa mukana siis on mahdollisuus 3D-mallintamiseen), siirtyminen kolmiulotteiseen suunnittelutyöskentelyyn olisi kirjaimellisesti erittäin lähellä, esim. toisessa työskentelyikkunassa tai näytöllä. Yksinkertaisimmillaan tämä tarkoittaisi suunnitelman piirtämistä 2D:nä toisella näytöllä ja mallintamista toisella. Esimerkiksi tukimuurin piirtäminen ensin ylhäältä päin ja sitten sen pursottaminen (extrude) viereisessä ikkunassa. Näin suunnitelmasta on mahdollista tuottaa perinteinen kaksiulotteinen viivapiirros (jossa Autocad on ylivertainen), mutta myös 3D-malli, joka on yhteensopiva monen muun 3D-ohjelman kanssa, onhan DWG-formaatti käytössä niin laajasti monella alalla. Tsemppiä diplomityön tekemiseen!

3D malllinnus on arkkitehtuurissa vakiintuneemmassa asemassa kuin maisemapuolella. Suunnittelualan tulevaisuus on 3D painotteista ja maisema-arkkitehtuurissa olisi hyvä kiriä. Varusteet ja laitteet saadaan yleensä jo malleina, jolloin voidaan tutkia esim leikkipaikan tilallisuutta myös katsojan näkökulmasta. Mallinnus antaa arvokasta tietoa mm varusteiden asennussyvyyksistä ja kansirakenteiden ja kasvualustojen syvyyskonflikteista. Mallinnus palvelee samalla myös suunnittelun ohella tietomallien jakoa ja VR sovelluksia.
Maisemallisesti tarkkaa lopputulosta on vielä tässä vaiheessa hankalaa tehdä 3D:nä työkalujen puuttuessa.
Olen eläkkeellä, 3Dn käyttö oli uutuus kun lopetin suunnittelutyön.
En ole löytänyt parasta mahdollista mallinnusohjelmaa. Kaikissa on puutteita etenkin maisemansuunnittelun kannalta. Näkökulmani on enemmän tietomallisuunnittelussa kuin visualisoinnissa.
Puhutaanko tässä nyt tietomallinnuksesta vai vain visuaalisesta 3d-mallinnuksesta? Eivät aina ole ihan sama asia vaikka nykyään kai enenevässä määrin. En tee kilpailuja tms, teen rakennusliikkeille pihasuunnittelua, on todettu että pihoista ei oikeastaan kannata tehdä tietomallia eikä visuaalista mallia, siis kustannukset ja hyöty eivät kohtaa. Yleensä myyntikuvat tilataan joltain eri toimistolta kuitenkin tai arkkitehti tekee, ja nekin tehdään pihan osalta kai enimmäkseen phtoshopilla. Jos haluaa mallintaa esim. elävän näköistä kasvillisuutta (versus liimaa puun kuvan rakennuksen 3d-kuvan päälle) se käsittääkseni edelleen vaatii ihan järjettömiä laskentatehoja. Ja jos haluaa tehdä töitä mobiilisti kannettavalla, ne tehot on kuitenkin rajalliset. Tunnustan että suunnittelen 10v vanhalla ohjelmistoversiolla koska en kaipaa mitään monimutkaistamaan sujuvaa ja nopeaa suunnitteluprosessia. Tiedän että jossain vaiheessa pian on pakko laittaa näppinsä tähänkin, mutta kun 20 vuotta on tehnyt jollain tavalla niin kynnys lähteä huvikseen tekemään tai harjoittelemaan jotain mistä asiakas ei halua maksaa on aika korkea.
Vesistöjen mallintamiseen ja esim. tulvien simulointiin on 3D työkalut tarpeen (olisi kiva oppia); mainitsin QGIS vaikkei se ole varsinainen 3D-mallinnusohjelma, mutta paikkatieto on oleellinen osa suunnitteluprosessia, en tiedä onko DEM-malleja avata muilla ohjelmilla...samoin mallinnusohjelman ja Google Earthin yhteensopivuus olisi hyödyllistä
Tietomallintaminen tulee jatkossa käyttöön monissa projekteissa ja sen kehittämisestä on käynnissä pääkaupunkiseudun yhteinen projekti MaisemaBIM
3d-mallinnus ja renderöinti eivät välttämättä ole enää kovin pitkään erillisiä prosesseja, sillä mallinnusohjelmiin lisätään koko ajan 3d-kiihdytettyjä ominaisuuksia ja vastaavasti reaaliaikaiseen renderöintiin lisätään perinteisiä raytracing-renderöintiominaisuuksia. Lisäksi pilvilaskenta ja tekoäly voivat nopeuttaa renderöintiä. Uudessa Geforce RTX-näytönohjainsarjassa käytetään jo tekoälyllä optimoitua reaaliaikaista raytracing-renderöintiä esim. heijastavissa pinnoissa, jolla saavutetaan parempi laatu kuin rasteroinnilla.
Käytän mallinnusta pääasiassa maastonmuotoiluun. Muita maisemaelementtejä tulee harvemmin mallinnettua (joskus muurit). En ole koskaan käyttänyt mallinnusta esim. rakennekerrosten laskemiseen - vain pinta on ollut käytössä.

Tärkeimpänä elementtinä 3D suunnittelun hyödyssä kuvittelen olevan, että sillä voidaan kuvata elävää ympäristöä ja luontoa tähänastisista tekniikoista kaikkein realistisimmin mm. erilaisten algoritmien avulla, joiden selvittämiseen/laskemiseen yksittäisellä ihmisellä tai kokonaisella työskentelytiimillä menisi ilman tietokoneen laskentaa ikuisuus. Puhun siis esimerkiksi tulva-, asvien asvu- sekä liiekennesimulaatioista. Lisäksi kehittyvänä alana se tulee olemaan tärkeä osa tulevaisuudessa työllistymisen kannalta, että maisema-arkkitehti osaa käyttää myös poikkialaisia työvälineitä ammattia harjoittaessaan. Esimerkiksi valtameren toisella puolen 3D malleja maisema-arkkitehtuurin suunnittelussa käytetään jo hyvää vauhtia.
Tsemppiä dippaan!
Se mitä tilaajatahot todella paljon haluaisivat edistää on tiedonsiirto (avoimet tiedonsiirtoformaatit, esim. IFC ja niiden tuottaminen eri ohjelmistoilla, niin että mukaan saa liitettyä tietoa) Se on oma laaja kokonaisuutensa, jota ei samassa diplomityössä kannatakaan käsitellä laajemmin, mutta on kuitenkin asia joka kannattaa pitää mielessä, kun mietitään ohjelmistojen kehitystä.. Eli iso osa tämänhetkisestä mallinnuspaineesta on myös tiedonhallintaan liittyvää, ei pelkästään sitä että halutaan nähdä ja suunnitella asioita 3D:ssä.
Maisemasuunnittelun suurin haste on maiseman ja sen kayton jatkuva dynaamisuus, mita on vaikea tulkita piirustuksin, ja varmaan myos mallinnuksin
Aallossa pitäisi panostaa enemmän 3D-ohjelmiin. Opetus on jotenkin tosi hankalaa/ei pysy mukana kun tuntuu niin hankalalta. Ja kurssit mielummin pelkkää 3D-harjoittelua, ei mukana osana esim studiota (kuten Pian kursseissa...) Tästä syystä en ole paljon käyttänyt 3D-ohjelmia ja on paljon puutteita niiden käytössä ja haluaisin oppia paremmin.
Toivoisin alan sisäistä keskustelua siitä, missä määrin 3D-mallinnus on todella hyödyllistä ja tavoiteltavaa ja missä määrin se on yksi homma lisää ja onko se täten tarpeellinen ja millaisissa projekteissa. Toisin sanoen painottaisin kysymystä, missä määrin mallinnuksella päästään parempiin suunnitteluratkaisuihin? Toinen kiinnostava kysymys on tietysti, mikä ohjelma meidän alalla olisi hyödyllisin ja mitä siis esimerkiksi koulutuksessa tulisi painottaa.
Yksi ongelma on se että tilaajilla ei välttämättä ole sopivia 3D ohjelmia tai eivät osaa niitä käyttää, jolloin on tärkeää että 3D:stä saisi helposti snap shotteja tai tietoja siirrettyä 2D-ohjelmiin.